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# People

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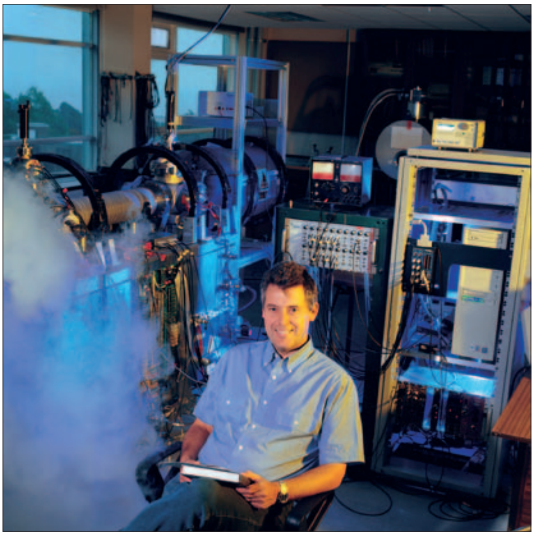
INTERVIEW

# Antimatter and a non-standard route to CERN

Mike Charlton talks to Gary Williams about his schooldays, his career path to CERN and his work on antimatter.



*Mike Charlton's early enjoyment of physics at school led on to a successful career at CERN.*

Mike Charlton is involved in the ALPHA experiment at CERN, which aims to perform detailed spectroscopic studies of the properties of antihydrogen atoms. The team at CERN has recently succeeded in trapping antihydrogen atoms in a magnetic-field minimum for periods of 1000 s or more and has observed the first resonant-quantum transition in the anti-atom. This is the first study of the spectroscopic properties of an atomic system made entirely of antimatter. At Swansea University Mike's group is performing experiments aimed at elucidating the properties of positronium. Pulses of positrons from a compact accumulator are used to do this. The group has learned how to rapidly compress positron clouds in this device to efficiently make a cloud of positronium for future study. Mike is also interested in positron interactions with gases, in particular annihilation and transport. He is the co-author of a book, *Positron Physics*, and author of the paper 'Antihydrogen on tap' published in *Physics Education* (2005 **40** 229), among many other publications.

**Please tell us a little bit about your experience of physics at school.**

It started before I knew what physics was. I always loved mathematics and in the last year at junior school my teacher decided not to include me in the regular maths classes, but allowed me to roam free through the text and exercise book. I taught myself the rudiments of algebra, which was to serve me well at secondary school. I attended Ferryhill Grammar Technical School in County Durham, where I was taught in subjects such as woodwork, metalwork and technical drawing, alongside the sciences and mathematics.

All went well and I chose the science route, starting in the third year (year nine now). The mock O-level in physics came as a shock. My teacher set a particularly hard paper, as I found out later, and I just about scraped through. As the months went by in the run-up to the O-level exam, I suddenly found that physics began to make sense. With the maths sorted, I didn't have to learn physics by rote; I could work it out. It was around that time that I made up my mind to try to go to university to study physics.

A-level was a joy. The experimental facilities at Ferryhill school were great and the standard of teaching was excellent. I even enjoyed wading through Nelkon and Parker. A change of teacher in the upper-sixth year introduced me to Whelan and Hodgson, which came as something of a revelation, and gave me a more questioning approach to the subject. All in all, I had a terrific experience with physics at school where I developed a passion for the subject that has never diminished.

**How did your experience of physics at university compare with how you think students now experience physics?**

I turned up at university in 1975 at a major London college. The physics class size was less than 40 in number; it is close to treble that figure now. The course I took had recently become modular; a system that seems to have stood the test of time.

Although lectures had long since ceased to be formal affairs, the lecturers were, by and large, unapproachable. You could please yourself whether or not you turned up for lectures (there was no formal register), you only had to pass exams. The lab was different; you had to show up and a board displaying which experiments you'd completed was there for all to see. Visual aids were non-existent and photocopied material was expensive, so it was almost all 'chalk and talk'. Problem sheets were regularly handed out and marked, although as far as I recall they didn't contribute to the assessment of the course. So you needn't do them if you couldn't be bothered. Much has changed in the meantime.

We were assessed by examination at the end of the academic year with papers for individual modules, as now. There was no September-resit system, so if you failed you were out or had to retake exams as an external the following year. The notion of concern being shown regarding student progression didn't seem to exist back then, or if it did it completely passed me by.

There was only the BSc degree available. Nevertheless, some of the topics that were covered, such as electromagnetism and quantum mechanics, were taught to a greater depth than is typical now. On the other hand there was no room for more exotic topics such as cosmology and gravitation, and on the whole there were fewer options available at an advanced level than there are nowadays to students on MPhys courses.

Physics departments back then were generously supplied with support staff. This infrastructure has dwindled over the years. However, it meant that my lab course included week-long sessions on technical drawing and electronics, and a stint in the mechanical workshop. I expect that the 'student workshop' is a thing of the past but I enjoyed it. And the fruits of my labour there—a miniature cannon, non-firing I'm afraid, on a wheeled carriage—still sit on a window ledge in my home.

**What was it that led you into antimatter?**

I started my final year undergraduate project in October 1977. In the department in which I studied one of the research groups had recently discovered a method to make a beam of low-energy positrons. It involved moderating the kinetic energy of the beta particles emitted from a radioactive source using a prepared solid, whereupon a small fraction of them were emitted from the solid into a vacuum at low energies, typically around 1 eV. Although this technique was only a few years old, one of their prototype beams was available in the third-year lab for use in a project. My lab partner and I chose it.

It turned out to be a lucky choice. The project went well and the research group recruited me into a PhD position, starting in autumn 1978. The positron-beam field was very young so there was a lot to do. And everything was interesting. It was an extremely exciting time and after my doctoral studies I was fortunate to be able to continue in the same research group as a research assistant and then a research fellow. So by the early 1980s I was well down the antiparticle route.

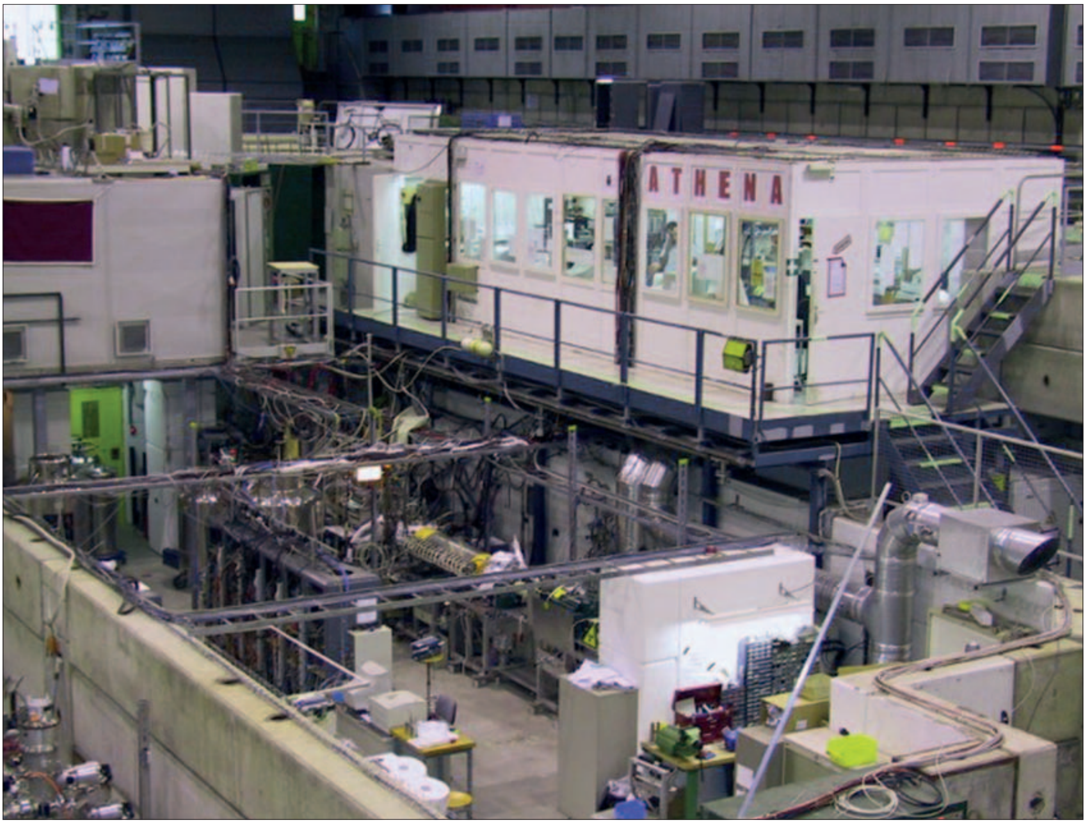
A few years later our group, together with a visitor from Denmark, was trying to improve our beams using ultra-thin metal foils to produce the low-energy positrons. We heard that a scientist at Aarhus University in Denmark could make these foils, so my Danish colleague visited him on his way home for a holiday.

He returned to the UK with some foils and also the germ of an idea. He'd met another scientist there by chance who was dreaming up schemes to try to make atoms of antimatter; namely, antihydrogen. We quickly figured out ways to improve on the initial ideas and so, all working together, we put pen to paper. My first work on antihydrogen was published in the *Journal of Physics* in January 1987. I didn't know then that atomic antimatter would become the sole focus of my scientific endeavours or what amazing progress the next quarter of a century would bring.

**Does the Higgs boson have any effect on your work?**

It already has had an effect, albeit indirect. To create antihydrogen we need access to a source of antiprotons. The rest-mass energy involved to create this antiparticle is close to 1 GeV, a giga-electron-volt. As a result, antiprotons can only be created in plentiful amounts at particle accelerator labs and we rely on CERN as the provider.

The LHC, where the Higgs was discovered, is the top-end user of a wonderful chain of particle sources and accelerators. CERN makes use of the facilities that it has developed over the years for a wide range of investigations on top of LHC physics. Antimatter science is one example. Indeed, although CERN is famous for its accelerators, it has also developed techniques to decelerate particles in some of its storage rings. It has a unique




*The Athena experiment.*

machine called the Antiproton Decelerator (AD), which captures antiprotons created at high energies and slows them down before delivering them to our experiments. We then do the rest to make antihydrogen.

The standard of facilities required to maintain our antihydrogen operation is not possible at university labs or at the type of national facilities that are available to most countries. It needs a world-leading laboratory such as CERN with a mission to go to the forefront of science.

We could survive without the LHC and the Higgs-boson discovery quest, but our lives are made much easier by working at the laboratory where this is taking place. And now that the LHC seems to be working like a Swiss watch, CERN has decided to invest extra resources in antimatter physics and create a little sister for the AD called ELENA. ELENA will provide extra low-energy antiprotons for us and will increase our antihydrogen-production capabilities by about a 100-fold. Long may the physics of the Higgs boson and beyond continue.

**Do other areas of physics have much of an impact on your antimatter work?**

Oh yes, most certainly, and in many ways other than just being the end user at a particle-physics lab. First, let's define where antihydrogen physics might sit. Antihydrogen is an atom, so we need the techniques developed by atomic physics, such as laser and microwave spectroscopy, and magnetic trapping, to develop our subject. So foremost, we naturally sit alongside our atomic-physics colleagues, and atomic physicists are an important part of the experiment that I belong to.

However, when an antihydrogen atom strikes matter an antiproton annihilates with some nuclear matter creating a characteristic bunch of energetic particles called pions. These are simple events compared with those that are being analysed to unearth the Higgs boson, but similar techniques are needed to detect them. So our annihilation detector was developed and is run by nuclear and particle physicists who work alongside us as we take the project forward.

Collecting the positrons and antiprotons and getting them ready for the delicate mixing procedure used to create antihydrogen with low kinetic energies requires an understanding of how clouds of these particles behave when held in charged-particle traps. Aspects of this belong to the realm of plasma physics and we have scientists from this area in our collaborative effort.

So antihydrogen physics is a marvellous hybrid, sitting at the interface of a number of rich areas of physics. Indeed, the techniques we develop to do our work mean that we don't just draw on these fields but feed back into them.

**If you hadn't gone into antimatter research what area of physics would you have followed?**

I started in antimatter research coming from an atomic physics background but with the added twist of doing my atomic physics with antiparticles. Coming up to the end of my undergraduate degree, the research path I chose was heavily influenced not only by the final-year project that I was doing but also by superb sets of lectures in quantum mechanics, which included the Dirac equation and the theory of the positron, and in particle physics.

Had I not had the stroke of luck to do the positron-beam project, I am sure that I would have gone into high-energy particle physics. It is highly likely that I would be working at the LHC with the Higgs boson now. Eventually my research did take me to CERN where our experiment is probing for new physics beyond the standard model. But I took a non-standard route to get there.

**How do you think physics teaching at university level is progressing compared with in schools?**

This is a tough question to answer. And doubly so for me as I have been a research fellow for the last five years, so have done very little teaching at undergraduate level during that period. I can only offer some broad-brush thoughts.

Over the years the manner in which students are taught and learn physics at university has evolved. I think the current jargon is that course delivery is now student focused and that progression is of paramount concern. This is likely to be true of most disciplines. This was not the case 35 years ago when, as far as I could tell, the academic system was mostly geared up to replenish its own ranks. Of course the majority of physicists have always gone on to careers outside academia but that was seen as something of a useful by-product. Today, and rightly so, it is acknowledged that a strength of studying physics is that the skills that are learned open up a broad spectrum of career paths.

*Peter Higgs spoke recently at Swansea University.*

It was pretty much the same in schools back then. Even at the grammar school that I attended, which took less than one in five pupils from my junior school, there was a massive cull after O-level, and many did not go on to university after the sixth form. So all in all there has been a massive change in the role and scope of education, right through to higher education.

I still feel, however, that there is a disconnection between physics at school and at university. It is not so much the course material but the manner in which it is delivered. Facing the challenge of the lecture theatre after the classroom is one thing, but the abstract and formal approach to the subject, which is still the norm from the outset at university, can be daunting for students. Working together across the school–university boundary to ease this tension would seem to be sensible to consider.

Physics is challenging and there is no way round this. Our curricula are crowded so learners face material that is disseminated at a fast pace. The rewards of studying physics at advanced level are many. It is from the school classroom that the next generations of physics students will come and we neglect the transition between the two at our peril.