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book reviews

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Engines of Discovery (A Century of Particle Accelerators). By Andrew Sessler and Edmund Wilson. Pp. ix + 212. Hackensack, NJ: World Scientific Publishing 2007. Price: (hardcover) GBP 29, USD 54. ISBN 978-981-270-070-4.

This book sets out to relate the real story behind the development of particle accelerators during the last century in a style which is anecdotal and non-mathematical. The two authors are well placed to accomplish their task having themselves spent long and productive careers in the field: Andy Sessler has been at Lawrence Berkeley National Laboratory since 1961 and Ted Wilson has been at CERN since 1967.

The book's format is somewhat unusual, being an A4 soft-covered glossy which is copiously illustrated with photographs and diagrams. The most notable feature is its use of 'side bars' or stand-alone text boxes in the manner familiar to scientific magazines. These are liberally, and perhaps even distractively, distributed throughout the book and provide detail on technical topics as well as biographical notes on a selection of individuals who have made significant contributions to the field.

The quest for some means to accelerate charged particles, the book relates, was prompted by Lord Rutherford, who had brilliantly demonstrated in 1910 the existence of the atomic nucleus by scattering 10 MeV α-particles, produced by the radioactive decay of radium, through a foil. But by 1928 in his inaugural address as President of the Royal Society, Rutherford was still yearning '... for a source of positive particles more energetic than those emitted from natural radioactive substances ...'. MeV particles were still a pipe dream but the theorist George Gamow predicted that the 1 MeV Coulomb barrier of light nuclei could be breached by 300 keV particles through quantum mechanical tunneling. This encouraged Cockcroft and Walton to build the first successful particle accelerator, a 600 keV DC voltage multiplier with which in 1932 they accelerated protons into a lithium target. This resulted in the first artificial transmutation of the nucleus and a Nobel Prize for both physicists.

The voltage multiplication technique of Cockcroft and Walton continues to this day to be employed as the first stage of acceleration for protons or ions at many major accelerators, and the authors give several examples. But in the 1930s the electrostatic accelerator invented by Robert Van de Graaff proved to be an easier and simpler undertaking, especially with a graded accelerating column and when enclosed in a tank pressurized with insulating gas. The story is told that the majority of nuclear cross-section data needed for the atomic bomb project at Los Alamos during World War 2 was produced by two Van de Graaffs which had been secretly shipped there from the University of Wisconsin. A cyclotron from Harvard was also used at Los Alamos but the Van de Graaffs churned out the data.

We learn how the cyclotron was invented by Ernest Lawrence in 1929 after reading the thesis of Rolf Wideroe which proposed a circular electron accelerator using induction to provide the accelerating potential. The thesis also discussed an earlier suggestion by Gustav Ising for a resonant linear accelerator in which the accelerating voltage is kept in resonance with the ions as their velocity increases. Lawrence made the crucial connection between bending the particles and automatically keeping them in resonance, the principle upon which the cyclotron relies.

The first cyclotron, built to use an existing 4 inch magnet, was constructed by Lawrence's graduate student Stanley Livingston at the University of California, Berkeley, and first evidence for resonant acceleration was obtained in November 1930. They immediately progressed to an 11 inch magnet to give an energy of 1 MeV, and this also worked well. But an astounding discovery was made by Livingston when, driven by curiosity and taking the opportunity provided by Lawrence's absence on a trip, he removed the wire grids covering the dees of the accelerating structure. Lawrence had firmly insisted on the need for these grids to generate a uniform accelerating field between them. To Livingston's surprise the cyclotron beam intensity increased by 100 times. Eventually it was realised that the curvature of the electric field between the dees in the absence of the grids was providing vertical focusing to the beam. A related effect, which also improved the beam intensity, could be obtained by slightly increasing the magnetic field at the center of the cyclotron. Thus the crucial role of focusing in particle accelerators was demonstrated.

This theme of explaining the background to important steps along the path which has led to today's sophisticated giant accelerators and, equally of interest, the personalities of those involved continues throughout the book. The chapters proceed logically through electrostatic accelerators, cyclotrons, linacs, betatrons, synchrotrons and colliders. Also covered are synchrotron radiation sources, accelerators for medical therapy, and the techniques of particle detection and how they apply to high-energy physics. The authors take every opportunity to explain the many actual and potential uses of particle accelerators from ion implantation to driving nuclear power reactors (with associated transmutation of high-level nuclear waste).

Synchrotron radiation sources earn themselves an entire chapter, not surprisingly since there are 54 dedicated facilities in 19 countries supporting more than 20000 researchers. Radiation from accelerated charges had been expected theoretically since the end of the 19th century, and in 1908 Schott had derived a complete treatment. This was not published and it remained until 1949 for Schwinger to publish his more elegant formulation. Meanwhile, in 1946, the General Electric Company had built a 100 MeV betatron and a measurable radiation effect was predicted. John Blewett confirmed that the beam orbit shrank near peak energy exactly as expected but he was otherwise unable to detect the radiation. (What is not told is that Blewett expected the radiation to be harmonics of the orbit frequency, but had found nothing when he searched with a microwave radio receiver.) As is now realised, relativistic effects shift the radiation to higher frequencies and at 100 MeV this results in visible light. In 1947, General Electric brought into operation at another facility a 70 MeV electron synchrotron which had a transparent glass vacuum chamber and the light was literally seen! It would have been observed earlier at the betatron if that had not used a ceramic chamber and one would now possibly be reading the 'Journal of Betatron Radiation'!

The penultimate chapter projects forward to the immediate future, with the Large Hadron Collider at CERN about to switch on, and with the next step already in progress as a global collaboration gets down to settling the detailed specifications for the International Linear Collider (ILC). For several decades there has been the tantalizing possibility that novel acceleration techniques based on lasers and plasmas will open a cheaper route to the TeV scale energy required by the ILC. Much progress has been made with these, although the authors' view is that it will take several decades before they could be used in earnest and may never match the very high requirements of high-energy physics.

In their final words the authors take pride in one immediate benefit from their lifetime field of work, namely that particle accelerators have provided an effortless opportunity for nations to forget their differences. The scale of future 'Engines of Discovery' is such that nations have no choice but to combine resources to create them. Young people brought together in the endeavor of building them have found that there need be no barrier between nationality, race or creed.

This book is fascinating reading for those already working in the field and will hopefully entice a fresh crop of young people who are contemplating a career either in accelerators, or in one of the many fields which use them, to join in. It is also highly recommended to those with a scientific background who wish to understand, in a non-mathematical fashion, some of the major tools for scientific discovery which the inventive genius of mankind has produced.

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