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Electron Lenses for Super-Colliders

By Vladimir D Shiltsev

Springer

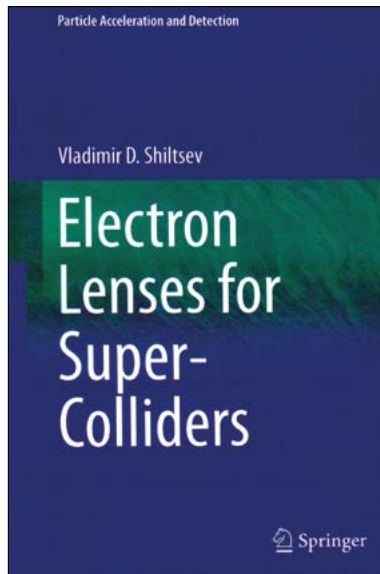
Also available at the CERN bookshop

With an energetic writing style, in this book Vladimir Shiltsev presents a novel device for accelerators and storage rings. These machines employ magnets to bend and focus particle trajectories, and magnets always create forces that increase monotonically with the particle displacement in the magnet. But a particle in a beam also experiences forces from the beam itself and from the other beam in a collider – forces that do not increase monotonically with amplitude. Therefore, magnets are not well suited to correct for beam-generated forces. However, another beam may do the job, and this is most easily realised with a low-energy electron beam stabilised in a solenoidal magnetic field – thus an electron lens is created.

The lens offers options for generating amplitude-dependent forces that cannot be realised with magnets, and such forces can also be made time-dependent. The electron lens is in effect a nonlinear lens with a rather flexible profile that can either be static or change with every passing bunch.

D Gabor already proposed the use of electron-generated space-charge forces in 1947 (*Nature* **160** 89–90), and E Tsyganov suggested the use of electron lenses for the SSC (SSCL-Preprint-519 1993). But it was Shiltsev who was the driving force behind the first implementation of electron lenses in a high-energy machine. Two such lenses were installed in the Tevatron in 2001 and 2004, where they routinely removed beam not captured by the radiofrequency (RF) system, and were used for numerous studies of long-range and head-on beam–beam compensation and collimation. In 2014, two electron lenses were also installed in the Relativistic Heavy Ion Collider (RHIC) for head-on beam–beam compensation, and their use for the LHC collimation system is under consideration.

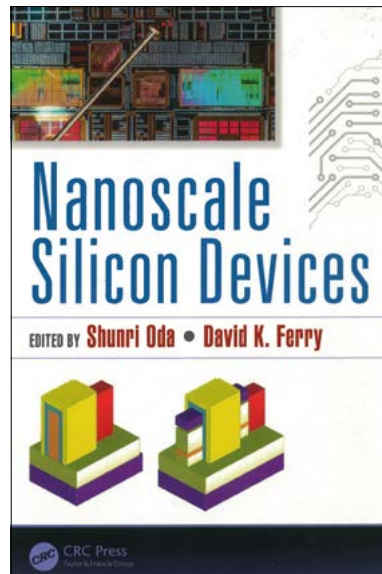
Shiltsev's experience and comprehensive knowledge of the topic make him perhaps the best possible author for an introductory text. The book is divided into five chapters: an introduction, the major pieces of technology, application for beam–beam compensation, halo collimation, and other applications. It draws heavily on published material, and therefore does not have the feel of a textbook. While a consistent notation for symbols is used throughout the book, the figures are taken



from other publications, and the units are mostly but not entirely in the International System (SI).

At the heart of the book are descriptions of the major technical components of a working electron lens, and the two main applications to date: beam–beam compensation and halo collimation. Long-range and head-on beam–beam compensation as well as collimation applications are described exhaustively. It is somewhat regrettable that the latest results from RHIC were published too late to be included in the volume (e.g. W Fischer *et al.* 2015 *Phys. Rev. Lett.* **115** 264801; P Thieberger *et al.* 2016 *Phys. Rev. Accel. Beams* **19** 041002). The book names the hollow electron lens a collimator, but it is probably better to describe it as a diffusion enhancer (as suggested on p138) because its strength is at least an order of magnitude smaller than a solid-state collimator, and a hollow lens will not replace either a primary or a secondary collimator jaw.

The last chapter ventures into more speculative territory, with applications that are not all in colliders. Most prominently, space-charge compensation is discussed, largely in terms of tune spread but not resonance driving terms. The latter is only mentioned in the context of multiple electron lenses (up to 24 for a simulated Fermilab Booster example). For this and the other applications mentioned, it is clear that much work remains before these could



become reality.

Overall, the book is an excellent entry point for anyone who would like to become familiar with the concepts, technology and possible application of electron lenses. It is also a useful reference for many formulas, allowing for fast estimates, and for the published work on this topic – up to the date of publication.

● Wolfram Fischer, Brookhaven National Laboratory.

Nanoscale Silicon Devices

By Shunri Oda and David K Ferry (eds)

CRC Press

The *CRC Handbook of Chemistry and Physics* was first published in 1913 and is a well-known text, at least to older physicists from the time before computers and instant, web-based information. To find relevant data, one had to be familiar with the classification of subjects and tables in the handbook's 2500 or so pages, but virtually everything was covered. Over the years, the CRC Press – while continuing to publish this handbook, for more than 100 years now – has grown into a large publisher that produces hundreds of titles every year in engineering, physics and other fields.

Its recent publication, *Nanoscale Silicon Devices*, describes a variety of investigations that are under way to develop improved and smaller electronic structures for computing, signal processing in general, or memory. Now that transistors approach the dimension of a few

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nanometres, less than 100 atoms in a row, methods to account for quantum effects have to be applied, as shown in the first chapter. The second chapter discusses the need to change the shape of transistors as they become smaller. The controlling gate has to extend as much as possible around the conduction channel material and, eventually, silicon may be replaced in the channel by a different semiconductor material.

Another effect due to the small size, as explained in chapter 3, is the increase of variability between devices of identical design. Single-electron devices and the use of electron spin are discussed in several of the following chapters. A major issue today, as highlighted in the book, is the reduction of power for circuits with a large number of transistors, where the leakage current in the OFF state becomes preponderant. In chapter 7, tunnel FET devices are discussed as a way to solve this problem. In chapter 6, a different approach is shown, using nanoelectromechanical ON/OFF switches integrated in the circuit.

This book is not a typical textbook, but rather a collection of 11 articles written by 20 scientists, including the editors Oda and Ferry. Each article centres on the research of its author(s) in a specific area of semiconductor-device development. One of the consequences of this structure is the abundance of internal references. Reading the book does not quite provide a firm idea about the future of electronics, but it could convince readers that much more will be possible, beyond the current state-of-the-art. One has also to keep in mind that the chip industry tends to keep useful findings under wraps and has little incentive to publish its research before products are on the shelves.

The book is a good buy if you want to get a feel about work going on at the interface between pico- and nanoelectronics. For the use of electronics in scientific research, it is essential to understand how devices are constructed and what researchers might be able to gain from them, especially when working in unusual environments such as a vacuum, space, the human body or a particle collider.

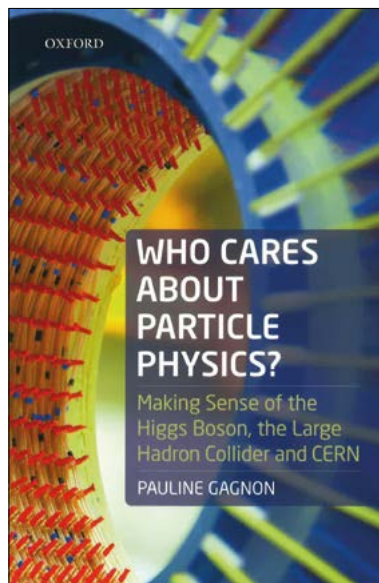
● Erik Heijne, CERN.

Who Cares About Particle Physics? Making Sense of the Higgs Boson, the Large Hadron Collider and CERN

By Pauline Gagnon
Oxford

Also available at the CERN bookshop

One of my struggles when I teach at my university, or when I talk to friends about



science and technology, is finding inspiring analogies. Without vivid images and metaphors it is extremely hard, or even impossible, to explain the intricacies of particle physics to a public of non-experts. Even for physicists, sometimes it is hard to interpret equations without such aids. Pauline Gagnon has mastered how to explain particle physics to the general public, as she shows in this book full of illustrations but without lack of rigour. She was a senior research scientist at CERN, working with the ATLAS collaboration, until her retirement this year (although she is very active in outreach). Undoubtedly, she knows about particle physics and – more importantly – about its daily practice.

The book is organised into four related areas: particle physics (chapters 1 to 6 and chapter 10), technology spin-offs from particle physics (chapter 7), management in big science (chapter 8) and social issues in the laboratory (chapter 9 on diversity). While the first part was expected, I was positively surprised by the other three. Technology spin-offs are extremely important for society, which in the end is what pays for research. Particle physics is not oriented to economic productivity but driven by a mixture of creativity, perseverance and rigour towards the discovery of how the universe works. On their way to acquiring knowledge, scientists create new tools that can improve our living standards. This book provides a short summary of the technology impact of particle physics in our everyday life

and of the effort of CERN to increase the technology spin-off rate by knowledge transfer and workforce training.

Big-science management, especially in the context of a cultural melting pot like CERN, could be very chaotic if it was driven by conventional corporate procedures. The author is clear about this highly non-trivial point: the benefits of the collaborative model we use at CERN in terms of productivity and realising ambitious aims. This organisational model – which she calls the “picnic” model, since each participating institute freely agrees to contribute something – is worth spreading in our modern and interconnected commercial environment, particularly because there are striking similarities with big science when it comes to products and services that are rich in technology and know-how.

As CERN visitors learn, cultural diversity permeates the Organization, and by extension particle physics. Just by taking a seat in any of the CERN restaurants, they can understand that particle physics is a collective and international effort. But they can also easily verify that there is an overwhelming gender imbalance in favour of men. The author, as a woman, addresses the topic of the gender gap in physics and specifically at CERN. She explains why diversity issues, in their overall complexity (not restricted to gender), are very important: our world desperately needs real examples of peaceful and fruitful co-operation between different people with common goals, without gender or cultural barriers.

For what concerns the main part of the book, which is focused on contemporary particle physics, chapters 1, 2, 3 and 6 are undoubtedly very well written, in the overall spirit of explaining things easily but nevertheless with full scientific thoroughness. But I was really impressed by chapter 4, on the experimental discovery of the Higgs boson, and 5, on dark matter, mainly because of the firsthand knowledge they reveal. When you read Gagnon's words you can feel the emotions of the protagonists during that tipping point in modern particle physics. Chapter 5 is an excursion to the dark universe, with wonderful explanations (such as the imaginative comparison between the Bullet Cluster and an American football match). The science in this chapter is up to date and combines particle physics and observational cosmology without apparent effort.

I recommend this book for the general public interested in particle physics but

also for particle physicists who want to take a refreshing and general look at the field, even if only to find images to explain physics to family and friends. Because, in the end, everybody cares about particle physics, if you can raise their interest.

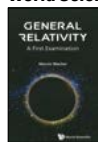
● Rogelio Palomo, University of Sevilla, Spain.

Books received

General Relativity: A First Examination

By Marvin Blecher

World Scientific



This book provides a concise treatment of general relativity (GR) ideal for a semester course for undergraduate students or first-year graduate students in physics or

engineering. After retiring from a career as an experimentalist in nuclear and particle physics, the author decided to teach an introductory course in GR at Virginia Tech, US. Many books are available on this topic, but they normally go into great detail and include a lot of material that cannot be covered in the short time of a semester. This new text by Blecher aims to cover this gap in the literature and provide just the essential concepts of GR.

The author starts with a review of special relativity and of the basic mathematical instruments, and then moves towards the explanation of the way that gravity affects time. This is discussed first for weak gravity via the conservation of energy using a Newtonian formulation with relativistic mass. Later in the book (chapter 5), it is rigorously treated in a completely GR framework. The Schwarzschild metric is also obtained.

In the following sections, GR is discussed in the context of the solar system (chapter 6) and of black holes (chapter 7). In the latter, an appealing example based on the movie *Interstellar* (Christopher Nolan) is used to discuss why a large gravitational time dilation is possible near a spinning – but not a static – black hole.

Chapter 8 focuses on gravitational waves. The first direct detection of these waves, produced by two black holes that merged into a single one, was announced

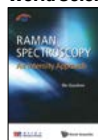
in February this year, when the book was already going to print. Nevertheless, the author added a discussion on this discovery to the text. The theory of the binary neutron star-system radiation, referred to the binary pulsar discovered by R Hulse and J H Taylor, is also treated, but in the case of elliptical orbits, instead of circular ones as generally done for simplicity in textbooks.

Finally, a chapter is dedicated to cosmology, in which the results of numerical integrations, using the experimental data available for all the energy densities, are discussed.

Raman Spectroscopy: An Intensity Approach

By Wu Guozhen

World Scientific



In this book the author offers an overview of Raman spectroscopy techniques – including Raman optical activity (ROA) and surface-enhanced Raman scattering spectroscopy (SERS) – covering their applications and their theoretical foundations.

The Raman effect is an inelastic two-photon process in which the incident (scattering) photon is absorbed by an atom or molecule (the scatterer) that immediately emits a photon of different energy and frequency than the incident one. This energy difference, which arises because the incident photon vibrationally excites the molecule, is called the Raman shift. Raman shifts provide information on the molecular motion and thus its structure and bond strength. As a consequence, this effect is used for material analysis in Raman spectroscopy.

More important than the energy difference are the Raman intensity of the scattered light, which offers insights into the dynamics of the photon-perturbed molecule, and the electronic polarisability of the molecule, which is a measure of how easily the electrons can be affected by the light.

After introducing the Raman effect and the normal mode analysis, the author discusses the bond polarisabilities, the

intensity analysis and the Raman virtual states. A group of chapters then cover the extension of the bond polarisability algorithm to the ROA intensity analysis and many findings on ROA mechanism resulting from the work of the author and his collaborators. The last chapter introduces a unified classical theory for ROA and vibrational circular dichroism (another spectroscopic technique).

Relativistic Density Functional for Nuclear Structure

By Jie Meng (ed.)

World Scientific



This book, the 10th volume of the *International Review of Nuclear Physics* series, provides an overview of the current status of relativistic density functional theories and their applications. Written by leading scientists in the field, it is intended both for students and for researchers interested in many-body theory or nuclear physics.

Density functional theory was introduced in 1970s and has since developed in an attempt to find a unified and self-consistent description of the single-particle motion in a nucleus and of the collective motions of the nucleus based on strong interaction theory. Largely applied for heavy and super-heavy nuclei, this description allows mapping the complex quantum-mechanical many-body problem of the structure of these nuclei onto an adequate one-body problem, which is relatively easy to solve.

After explaining the theoretical basics of relativistic (or covariant) density functional theory, the authors discuss different models and the application of the theory to various cases, including the structure of neutron stars. In the last chapter, three variants of the relativistic model and the non-relativistic density model are compared. Possible directions for future developments of energy density functional theory are also outlined.

Readers interested in further details and specific research work can rely on the very rich bibliography that accompanies each chapter.

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