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Accelerator Physics at the Tevatron Collider

By Valery Lebedev and Vladimir Shiltsev (eds)

Springer

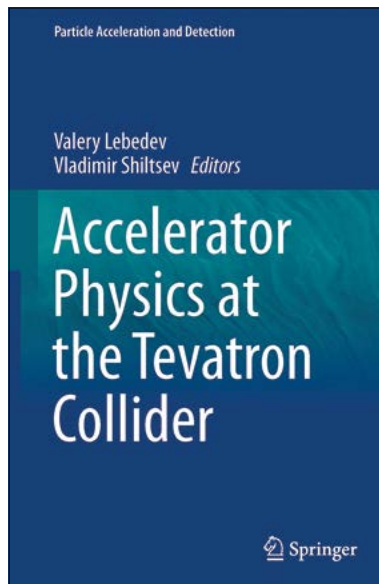
Hardback: £99 €116.04 \$149

E-book: £79 €91.62 \$119

This fascinating book, compiled and edited by two of the leaders of Tevatron's Run II, describes the achievements and lessons from Fermilab's famous machine, which shut down for the last time at the end of September 2011. The authors and editors take us on a mesmerizing tour through the components and history of this remarkable accelerator, and provide a lively account of how, across the years, numerous obstacles were overcome, and how novel technologies contributed to the astonishing success of "one of the most complex research instruments ever to reach the operation stage". Not only was the Tevatron the highest-energy particle collider for about a quarter of a century, it was also a pioneering accelerator in almost every regard.

In the first of nine chapters, Steve Holmes, former Fermilab accelerator director, John Peoples, former Fermilab director, together with Ronald Moore and Vladimir Shiltsev, recall the history of Fermilab and the "Energy Saver/Doubler", which was later to become known as the Tevatron. Across almost three decades, the peak luminosity of this collider was increased by four orders of magnitude. The second chapter, in which Alexander Valishev joins the two editors as author, surveys the Tevatron's linear and nonlinear beam-optics control. I particularly enjoyed the review of the intricate and spectacular nonlinear dynamics experiments performed in the late 1980s and early 1990s, which had been conceived to unveil the origin of dynamic aperture (e.g., the famous "E778 experiment") and the effect of tune modulation.

The third chapter, by Jerry Annala and co-workers, brings us to the heart of the accelerator. As the first superconducting hadron storage ring, the Tevatron designers and operators had many issues to tackle. These included the effects of large intrinsic nonlinear field errors; the dynamic chromaticity drifts owing to the decay of persistent-current field errors, whose successful automatic compensation depended on many details of the preceding magnet cycles, such as the length of the flat top, the ramp rate, etc; and, last but not least, the "snapback" – i.e. the sudden re-induction of the persistent currents in the superconducting cable at the start of



the energy ramp. From my student days, I vividly remember how much the Tevatron experience guided the development of the later superconducting machines, such as HERA at DESY. This chapter also presents the Recycler, the first large-scale all-permanent-magnet storage ring, operating at 8 GeV.

In the following chapter, Chandra Bhat, Kiyomi Seiya and Shiltsev present two of the most fascinating techniques of longitudinal beam manipulation – slip stacking, which has doubled the proton intensity in the Main Injector, and radiofrequency barrier buckets, used for the accumulation and processing of antiprotons. Next, Alexey Burov, Lebedev and their colleagues discuss the Tevatron's impedance and collective effects. There are noteworthy handy formulae for the transverse and longitudinal impedance of laminated vacuum chambers developed for the Tevatron, which I have used myself often.

Chapter six, by Richard Carrigan and several co-authors, treats mechanisms of emittance growth and beam loss, including important mitigation measures such as collimation, beam removal from the abort gap using the "Tevatron electron lens" as a pulsed exciter, tests of halo deflection with bent crystals, and the Tevatron luminosity model. Lebedev, Ralph Pasquinelli and others then delve into antiproton production, stochastic cooling and the first relativistic electron cooler, based on a 4.3 MV pelletron,

which many of my colleagues had thought to be unfeasible. The antiproton source technology, which had begun at CERN, was brought to maturity at the Tevatron complex, where from 1994 to 2010 the antiproton intensity was raised by another factor of 10, making this the most powerful antiproton source constructed, by far. In chapter eight, Shiltsev and Valishev discuss beam-beam effects, including the famous "scallop"-shaped pattern of emittance growth along the antiproton bunch trains, which I witnessed myself fill after fill around the year 2002, while visiting the Tevatron control room. Finally, advanced beam instrumentation, including Schottky monitors and proton synchrotron-light diagnostics, are summarized in chapter nine.

At the end of the book I found a list of about 30 PhD theses, completed on accelerator-physics topics at the Tevatron across a span of about 25 years. I smiled when I realized that many of these earlier PhD students have become today's leaders in the accelerator field. This illustrates the exceptional training experience from participating in a demanding and inspiring collider programme such as the Tevatron's.

Undoubtedly, this book will serve as a wonderful and unique reference for many decades to come. The authors and editors are to be congratulated for their effort to compile and preserve the accelerator knowledge of the Tevatron, accumulated during 25 years of successful struggle and permanent innovation. The Tevatron's lessons and achievements would be all too easily forgotten without such a written record. In conclusion, I recommend this book highly to accelerator professionals around the world. Reading it should be all but compulsory for anyone wishing to improve the performance of an existing frontier machine, or design the next generation of highest-energy colliders.

● Frank Zimmermann, CERN.

Beam Dynamics in High Energy Particle Accelerators

By Andrzej Wolski

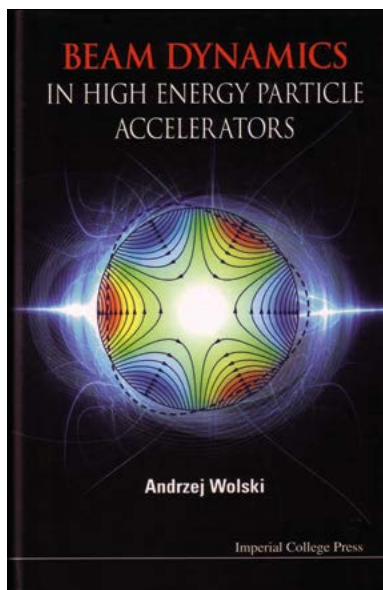
World Scientific

Hardback: £98

E-book: £74

This book by Andrzej Wolski is not a general textbook but, rather, a theoretical monograph on some of the basic physics of particle accelerators, with a strong emphasis on what can be treated analytically. It is decidedly not an introduction to accelerators. Indeed it contains no description, photo or diagram of

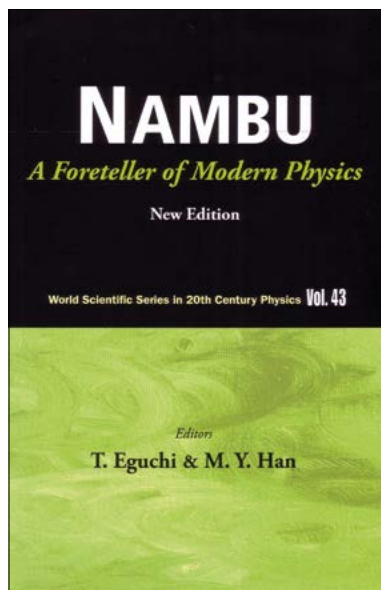
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what a particle accelerator looks like, no list of numerical parameters, nor any indication of what purposes such a device might serve. I could find no mention of the name, or energy, of any past or present accelerator. The unit of MeV first appears in relation to the spacing of spin resonances. I wonder whether the author consciously sought to imbue his work with a whiff of Whittaker's treatise? No criticism intended – I rather admire his temerity – just make sure that you have some background before tackling this 590-page opus.

The first two words of the title are key to its coverage: beam dynamics is treated as an application of classical Hamiltonian mechanics and electrodynamics. These are the explicit prerequisites. Among existing books, those of S Y Lee (a little shorter and denser) and H Wiedemann (almost twice as long), are pitched at a similar level, but structured as textbooks with exercises and more applications.

I liked chapter one, a useful description of the electromagnetic fields in magnets and RF cavities that goes into more depth than most, and is careful to explain some key practical concepts that are sometimes taken for granted. On the other hand, there is no mention of how strong you can make those fields. Subsequent chapters cover thoroughly the well-trodden ground of linear single-particle dynamics and optics in the two transverse degrees of freedom, taking a Hamiltonian approach *ab initio*. I was a little disappointed in the perpetuation of an unfortunate choice of the canonical variables for longitudinal motion, first made



in a well-known computer program in the 1980s. Perhaps it is as well to follow the crowd now, but subsequent Hamiltonians become messier than necessary, and there is some unnatural fudging around the dispersion function.

Unusually, but logically, longitudinal motion is treated in the context of a chapter on coupling, before the introduction of a formalism for full linear coupling. There is a standard discussion of synchrotron radiation (omitting the quantum lifetime) and low-emittance lattice modules for light sources. Nonlinear dynamics gets a great deal of attention, with discussions of the traditional topics of Lie transformations, canonical perturbation theory, symplectic integrators, nonlinear resonances, dynamic aperture and frequency map analysis. Practical results on linear perturbations are also worked in.

Like Lee and Wiedemann, Wolski says surprisingly little about colliders. There is no mention of low-beta collision optics, dispersion suppressors or separation schemes. A brief discussion of the head-on beam-beam effect and a passing mention of luminosity are appended to a more comprehensive discussion of single-beam space charge. Perhaps this reminds us that most accelerators are not colliders. There is a good derivation of the Touschek lifetime, but the standard results on intra-beam scattering (Piwinski, Bjorken-Mtingwa) are only quoted.

The final chapters cover wake-fields and impedances, and the collective instabilities they drive. The formal approach works

well here, imposing order and clarity on what can be a confusing array of concepts and definitions. Several important beam-instability mechanisms are treated in detail.

The book seems relatively free of misprints (although there is a glaring one after equation 2.17). Overall, this is a recommendable addition to the literature, covering its topics clearly and thoroughly.

● John Jowett, CERN.

Nambu: A Foreteller of Modern Physics

By T Eguchi and M Y Han (eds)

World Scientific

Hardback: £45

E-book: £23

Seeds for many developments in contemporary particle physics were sown by Yoichiro Nambu in his lectures and papers in the 1960s and 1970s – in particular, his work on the mechanism of spontaneous broken symmetry, for which he was to receive the Nobel prize (*CERN Courier* November 2008 p6). Tackling first the problem of maintaining gauge invariance in a field theory of superconductivity, he went on to develop these ideas in field theories for elementary particles, in particular inspiring the important work that led to the Brout–Englert–Higgs (BEH) mechanism for generating mass through spontaneous symmetry breaking in the Standard Model. These developments culminated at CERN in July 2012 (not 2011, World Scientific please note) with the discovery of an appropriate scalar particle – a Higgs boson. This book collects together the important papers related to this story and much more, some never published before in book form. The text is not only of historical value, but also provides a window into the mind of a man that many refer to as “Nambu the seer”. It is a valuable resource for researchers in elementary particle theory, and for those who are interested in the history of modern physics.

● Christine Sutton, CERN.

Books received

Path Integrals and Hamiltonians: Principles and Methods

By Belal E Baaquie

Cambridge University Press

Hardback: £75 \$120

E-book: £96



Providing a pedagogical introduction to the essential principles of path integrals and Hamiltonians, this book describes cutting-edge quantum-mathematical techniques applicable to a vast range of fields, from quantum mechanics, solid-state

physics, statistical mechanics, quantum field theory and superstring theory to financial modelling, polymers, biology, chemistry and quantum finance. The powerful and flexible combination of Hamiltonian operators and path integrals is used to study a range of different quantum and classical random systems. With a practical emphasis on the methodological and mathematical aspects of each derivation, this introduction to these mathematical methods is suitable for researchers and graduate students in physics and engineering.

Principles of Discrete Time Mechanics

By George Jaroszkiewicz

Cambridge University Press

Hardback: £85 \$130

E-book: \$104



Could time be discrete on some unimaginably small scale? Exploring the idea in depth, this book systematically builds the theory up from scratch, beginning with the historical, physical and mathematical background to the chronon hypothesis. Covering classical and quantum discrete-time mechanics,

the author presents all of the tools needed to formulate and develop applications of discrete-time mechanics in a number of areas, including classical and quantum mechanics and field theories.

Reviews of Accelerator Science and Technology: Volume 6 – Accelerators for High Intensity Beams

By Alexander W Chao and Weiren Chou (eds)

World Scientific

Hardback: £98

E-book: £74

Also available at the CERN bookshop



As particle accelerators strive for ever-increasing performance, high-intensity particle beams are becoming one of the critical demands from a majority of users – whether for proton, electron or ion beams – and for most applications. The accelerator community has therefore put a great deal of effort into the pursuit of high-intensity accelerator performance, on a number of fronts. Recognizing the topic's importance, the editors have dedicated this volume of *Reviews of Accelerator*

Science and Technology to accelerators for high-intensity beams. As well as reviews of applications at the intensity frontier in particle and nuclear physics, this volume also looks at applications, for example, in radiography and the production of radiopharmaceuticals, as well as in accelerator-driven systems and the inertial production of fusion energy. Other chapters deal with different types of accelerator, such as superconducting hadron linacs and rapid-cycling synchrotrons, and accumulator rings for high-intensity hadron beams. Key accelerator subsystems that allow high-intensity operation are also covered, with chapters on ion injectors, ion charge-strippers, targets and secondary beams, neutron-beam lines and beam-material interactions. The final chapter follows the journal's tradition of looking at people who have shaped the field. This time, Giorgio Brianti and David Plane contribute their personal recollections about John Adams, who made so many pioneering contributions to CERN's unrivalled accelerator complex. In particular, it outlines Adams's abilities as an international collaboration leader.

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