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BOOK REVIEW

Introducing the world's most famous particle accelerator to its stakeholders

Don Lincoln: The Large Hadron Collider: The extraordinary story of the Higgs Boson and other stuff that will blow your mind. Baltimore: John Hopkins University Press, 2014, xii+223pp, $29.95 HB

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Don Lincoln, author of this introduction to the Large Hadron Collider, has written other books bent on clarifying concepts of particle physics to the general reader. An experimental particle physicist at both Fermilab and CERN, he knows whereof he speaks. Lincoln's explanatory skills earned him the 2013 European Physical Society's High Energy Particle Physics Board's Outreach Award "for communicating in multiple media the excitement of High Energy Physics to high-school students and teachers, and the public at large." Knowing these things, when picking up this compact book of eight chapters, the reader should expect to find it written in accessible language and an engaging manner. I regret to report, however, that, while every page conveys the author's enthusiasm for what he does, the book's reading level is very uneven.

Marketed as a trade book and not as a textbook, much of the book is perfectly comprehensible to the average reader of, say, *The New York Times* or *New Scientist*. The second half of the book, however, has enough very technical sections to scare off less dedicated general readers. Lincoln's awareness of the issue "of having a diverse readership" (23) is not hidden. Occasionally, he says the equivalent of "what you are about to read isn't easy, so we'll go slowly." But going slowly doesn't guarantee comprehensibility. The book's subtitle promises that some of the contents "will blow your mind," but all too often the coverage verges on crippling the brain. Nonetheless, readers who persevere, perhaps skipping over whole paragraphs and even pages here and there, will find a lot of interesting material, and should come away with a deeper appreciation of the author's subject.

I like Lincoln's suggestion that his readers are all stakeholders in the project: "It is likely if you're reading this that…through a tiny fraction of your annual taxes, you have personally contributed to this unparalleled scientific mission" (viii–ix),

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which, he points out, is “the most powerful scientific instrument ever devised to study the most fundamental questions of the universe, such as how it evolved and why it has to be the way it is” (4). Our support, however inadvertent, means that all of us “should know what [we] are getting for [our] money”—namely, that the nearly 10,000 physicists and technical professionals working at the LHC are “coming to understand the deepest rules that govern matter and energy, space and time” (ix). (As author of science textbooks and biographies for younger readers, I was interested to infer from the suggested reading at the end of the book that Lincoln has reached out even to future LHC stakeholders: He was scientific consultant on a 2013 book for eight- to ten-year-olds, also called *Large Hadron Collider*).

Early in the book, Lincoln’s sensitivity to readers’ different interests is clear. While it would be “inexcusable,” he says, “not to describe the accelerator and its detectors—some of the coolest scientific equipment ever built”—the subject of chapters 3 and 4—he recognizes that “some readers just aren’t gadget people. These are the same people who want their cars to run and their cell phones to work without a shred of curiosity as to the innards of these devices” (23). He suggests that those readers “only skim the next two chapters and pick up the narrative again in chapter 5” (23). Despite his caveat, I was pleased to see how Lincoln’s sense of humor in those two chapters lightens what might otherwise be a tedious enumeration of technical details. A few examples: “If you have a bunch of protons, how do you cause them to go fast? A slingshot? Draft a pitcher from Major League Baseball? Attach them to a three-year-old and feed him sugared breakfast cereal? Well, while all of these approaches might have their merits, the reality is a bit more practical” (25); “using magic in a physics laboratory is usually considered a poor choice, what with the rabbit fur and dove feathers getting into everything” (31); “in the polyglot environment of CERN,” at times of stress, it “can be an entertaining thing to experience” how “[s]ome languages really do have a flair for invective” (44).

Not a gadget person myself, I wasn’t expecting to find so much of interest in chapter 4, “Incredible Detectors.” Lincoln does a good job explaining the process of analyzing “what amounts to fast and high-tech photographs” (55) that record the billions of collisions between protons. He introduces a term with which I was previously unfamiliar: An *event display* is the name for the collision image that scientists study.

He compares the challenge facing an experimental physicist in interpreting those event displays to that facing a bomb-squad investigator trying to understand the explosion by carefully observing how it has affected its surroundings. Just as the bomb investigator has to assess “scorch marks, total damage, amount of debris, and how deeply the shrapnel penetrates well-understood materials” (55), and has to perform chemical analysis to shed more light on the problem, a particle physicist, having surrounded the collision point with a detector whose properties are well understood, can learn a lot by “seeing how the particles leaving the collision interact with the detector” (56). The trained eye can infer the energy, trajectory, and point of origin of the particles that emerge from the collision, and then—much as one does in assembling a complicated jigsaw puzzle—painstakingly piece together the information revealing what the initial collision was like. (Such analogies, of course, were used to describe “atom smashers” long before LHC was a gleam in anyone’s eye.) Lincoln then does a thorough job of explaining the several “clever techniques” (57) scientists use to identify particles, including magnetic bending, ionization, showering, transition radiation, and Cerenkov radiation.

I was also interested to read that scientists have to know which collisions to record in order to get important data to analyze. Interesting collisions are much rarer than I realized, which Lincoln engagingly explains: “Most collisions at the LHC will be relatively gentle impacts between two protons passing by one another, like two strangers brushing shoulders as they pass one another on a street in New York City. However, like the beginning of many a light romantic comedy, occasionally two protons collide violently and some noteworthy physical process is revealed” (86). The choices that experimental particle physicists must make seem both momentous and daunting: “If you choose the wrong collisions to record and you don’t have the right data to analyze, you might as well pack it up and go home” (86).

Among the amusing “LHC War Stories” with which chapter 4 concludes is one about the ten-day trip to transport the most powerful large magnet ever constructed from the point of its assembly in Genoa, Italy, through the streets of Cessy, France, near the experiment site, and then finally to the detector hall. “No houses were scraped in the process, although there were a couple of times when the onlookers held their breath” (104).

Even though I personally found much of the rest of the book very challenging, I learned a lot of interesting things. Lincoln explains that searching for the Higgs boson—the detection of which at the LHC made front-page news the world over in 2012, resulting in two Nobel prizes—is an example of a discovery made not through finding something unexpected but by investigating a clear prediction from a theoretical idea to see if the idea is true. He explains why it is so difficult to identify events in which the Higgs boson was created by discussing how difficult it would be to pick out a single diamond placed into a bucket of cubic zirconia, which closely resemble diamonds. Lincoln’s discussion about the choice of recipients for the 2013 Nobel prize is well worth reading, even if the reader hasn’t understood all the details about why detecting the Higgs boson was so difficult.

In concluding chapter 7, which suggests questions the LHC may consider in the future, Lincoln admits he has no idea what the next big LHC discovery will be but suggests “it may be something utterly unexpected; something that just hits us out of the blue” (206). That turns out to be a prescient remark, and one that confirms the title of the book’s final chapter, “The Future Is Bright.” On the very day I finished reading the book, news articles announced that LHC scientists had “stumbled on” (*The Wall Street Journal*, July 15, 2015, A11) an exotic particle—the pentaquark—that physicists had sought for over five decades. In the 1950s, American physicist Murray Gell-Mann proved that every proton and neutron is made of combinations of three quarks, but proposed that, theoretically, matter could also be made of five quarks bound together. Pentaquark sightings reported as early as 2003 were later invalidated. Recently, however, in reviewing LHC particle collisions done between 2011 and 2012, scientists there chanced upon a large spike in one of the readings that hinted at the pentaquark. After an additional six months of work, the team determined this finding was real. The discovery should not only shed light on scientists' understanding of the strong force but may also illuminate the makeup of neutron stars that form when giant stars collapse. Lincoln's readers may thank him repeatedly over the years to come for sparking their interest in the subject, as scientists at the LHC continue "to search for the answers to the ultimate questions" (211), such as "Why is the universe the way it is? Could it be different? If so, why this way and not others? What are the most basic rules of force and matter, of space and time—the rules from which all other rules are derived?" (208–209).