Shifting Standards: Experiments in Particle Physics in the Twentieth Century

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Raising the bar for statistical rigor

Shifting Standards
Experiments in Particle Physics in the Twentieth Century

Allan Franklin
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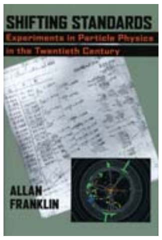
Reviewed by Paul Halpern

As Allan Franklin rightly points out in his informative new book, *Shifting Standards: Experiments in Particle Physics in the Twentieth Century*, the Higgs boson discovery in 2012 was a high-water mark for media coverage of the role of statistics in particle physics. Numerous news articles at the time drew attention to the litmus test for gauging whether the detected signals conclusively heralded the expected Higgs decay: a significance of at least five sigma (standard deviations) from the background distribution. In other words, the odds of such signals appearing by chance would be less likely than landing 20 heads in a row in a coin toss.



Demonstrating that such a strict cutoff has a makeshift quality, Franklin calls for a reasoned analysis of an experiment's specific conditions, including the suppositions of researchers and the factors that contribute to the background. Drawing on numerous detailed examples, he argues that a simple numerical criterion is far from the full picture. And yet, five sigma has become the standard for high-energy physics—a measure by which papers claiming discovery have been accepted or rejected.

Through a series of case studies spanning many decades, Franklin expertly shows how the five-sigma rule emerged from less demanding statistical standards. The jump in expectations has coincided with an enormous increase in researchers' ability to collect and process vast quantities of data, such as from the ATLAS and CMS detectors of CERN's Large Hadron Collider and formerly from the DZero and CDF detectors at Fermilab.

Of course, early 20th-century experiments—for example, Robert Millikan's famous oil-drop studies in the 1910s of the fundamental charge of an electron—involved far smaller data sets. Millikan's notebooks indicate only 175 drop values, half of which were discarded in his 1913 paper. "Millikan's selectivity and exclusion were hidden from the physics community," notes Franklin. Standards back then were far looser, yet physics progressed.

Franklin offers interesting cases of clashes resulting from disagreements about statistical measurements. Disputes over the reality of purported dark-matter particle findings offer a prime example. Some groups have claimed detection of such particles; others have been skeptical and have pointed fingers at what they see as inadequate statistical analysis. A smoking gun to some is just smoke and mirrors to others.

Although it is a well-researched book, *Shifting Standards* seems targeted at a limited audience: readers with a strong background in the terminology and methods of particle physics. Nonspecialists will no doubt find the author's detailed accounts of various experiments hard to follow. Often, Franklin introduces technical nomenclature—Monte Carlo simulations, scattering angle, scintillation, silicon vertex detectors, torsion balances—with not even simple definitions, let alone explanations. The style he uses matches the dry, precise language of technical journals rather than the more inviting discourse of books aimed at nonspecialists. He presumes that readers are familiar enough with the standard model and its components that they would understand why experimenters would wish to record certain types of interactions and seek particular parameters.

That said, *Shifting Standards* serves as a valuable, albeit specialized, guide to the history of statistics in high-energy physics. Franklin's study is timely, given the increasing requirement for modern discoveries to be validated by the weeding out of untold terabytes of background data, by running simulations, and by using statistical techniques that reveal a glimpse of a rare, fleeting interaction. His background is well suited for this exposition. He has published amply in the history and philosophy of science, including many books and articles about milestones in particle physics.

In a visit to the ATLAS experiment some years ago, I spoke with several graduate students and asked them what their day-to-day tasks were like. Most were involved with computer simulations rather than hardware. What a far cry from my own graduate days, I thought, when working with cables, counters, monitors, and duct tape in a stifling trailer or subterranean enclave was a universal initiation to the field. Any young researcher thinking of studying high-energy physics today would do well to delve into *Shifting Standards*. When it comes to the business of identifying new particles and measuring their parameters, avoiding statistics would be a bad bet.

Paul Halpern is professor of physics at the University of the Sciences in Philadelphia and the author of several books, including *Collider: The Search for the World's Smallest Particles* (Wiley, 2009).

The Science of Ocean Waves
Ripples, Tsunamis, and Stormy Seas

J. B. Zirker
Johns Hopkins U. Press, 2013. $39.95
(248 pp.). ISBN 978-1-4214-1078-4

Few topics in physics can match the complexity of air–sea interactions. So it is no wonder that an astrophysicist, a practitioner in a similarly complex system, took up the challenge of summarizing for the general reader the modern scientific view on ocean waves.

In his new book, *The Science of Ocean Waves: Ripples, Tsunamis, and Stormy Seas*, J. B. Zirker offers a comprehensive and up-to-date account of a familiar phenomenon whose complexity is hardly appreciated by nonscientists. Zirker's deep insights, historic perspectives, and excellent narrative, which he provides with minimal graphics and without a single equation, make the book a fascinating read. It is also an unusual approach to a topic that has com-