The Evidence for the Top Quark

Objectivity and Bias in Collaborative Experimentation

The Evidence for the Top Quark offers both an historical and a philosophical perspective on an important recent discovery in particle physics: the first evidence for the elementary particle known as the top quark. Drawing on published reports, oral histories, and internal documents from the large collaboration that performed the experiment, Kent Staley explores in detail the controversies and politics that surrounded this major scientific result.

At the same time, the book seeks to defend an objective theory of scientific evidence based on error probabilities. Such a theory provides an illuminating explication of the points of contention in the debate over the evidence for the top quark. Philosophers wishing to defend the objectivity of the results of scientific research must face unflinchingly the realities of scientific practice, and this book attempts to do precisely that.

This book will prove to be absorbing reading to a broad swathe of readers including philosophers, physicists, and historians of science.

Kent W. Staley is Assistant Professor of Philosophy at Saint Louis University.

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KENT W. STALEY
Saint Louis University

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For Dianne

Contents

Figures and Tables

FIGURES

TABLES

Preface and Acknowledgments

The origins of this project are located along a lonely stretch of Interstate 80 in Iowa in the early 1980s. Drasko Jovanovic, head of the Physics Department at Fermi National Accelerator Laboratory at the time, was in charge of Fermilab's "summer student" program. Students in the program had the opportunity to work in experimental groups at the lab and to learn about high energy particle physics. While driving along I-80 one day, Jovanovic saw a sign announcing "Grinnell College, next exit," which prompted him to note that Fermilab had not hosted a summer student from Grinnell in a while. I was the next Grinnell student to apply for the program. I spent the next two summers bending light guides and stringing cables under the imperturbable guidance of Fermilab physicist Mike Crisler, in the somewhat infamous "E-711" group.

More than ten years later, I was fishing around for a dissertation topic, and I called Drasko to ask whether anything interesting was happening at Fermilab. He dropped rather broad hints that something really big was in fact just about to happen: "I can't speak too freely on the phone, but . . ." He suggested that I call back in about a week. That was on April 19, 1994. Exactly one week later, the *New York Times* ran the headline, "Top Quark, Last Piece in Puzzle of Matter, Appears to Be in Place," on page 1. The historical and philosophical investigations presented here center on the events leading up to that headline.

Serendipity alone could not have brought about the completion of this project, however. For that I needed also the assistance of many people. Indeed, the nature of this project necessarily depends directly or indirectly on the efforts of a great multitude – indeed of more people than I can mention.

But I might start by referring you to oral histories listed in the references to this work. There you will find listed those who, through conversations, interviews, and e-mail messages, did their best to keep me out of the darkness of error. I want to thank especially those who took the time to read the

dissertation that I wrote and to share their reactions with me. A few were especially generous with their time and deserve special mention. Henry Frisch played a special role in the early stages of my investigations, both encouraging me and putting me in touch with many other people. Henry also directed my attention to the inherent interest of the problem of bias. Tony Liss was especially generous in helping me to understand the process by which the Evidence paper was produced, and many of the details of the analysis described in that paper. Dave Gerdes and Bruce Barnett both served on my dissertation defense committee and provided me with very valuable guidance with respect to both matters of historical fact and philosophical argument. G. P. Yeh provided me with very detailed accounts of some of the debates within the collaboration over the Evidence paper results. I benefited tremendously from correspondence with Morris Binkley, Joe Incandela, Krys Sliwa, Paul Tipton, and John Yoh. I am grateful as well to Boaz Klima of the D-zero collaboration for providing me with his reactions to my project. To him and to the physicists of D-zero in general, I wish to express my regret that I could not give D-zero's search for the top the same kind of detailed attention that the CDF (the Collider Detector at Fermilab) collaboration receives in this work.

Lillian Hoddeson and Adrienne Kolb at Fermilab helped me by advising me about who to talk to and by helping me find my way through the Fermilab archives. Carol Picciolo, CDF's secretary, helped me to navigate around the collaboration and advised me on how to deal with the lab bureaucracy. While conducting research at Fermilab, I have at various times relied heavily on the apparently inexhaustible hospitality of my friends Chris McKeachie and Deb Saeger of Oak Park, Illinois.

Many times in the pursuit of this project I have sought correction and advice from physicists not directly involved in the search for the top quark, particularly in my work on Chapter 1. Both Jonathan Rosner and Serge Rudaz gave me helpful feedback on some of the ideas developed in that chapter. Roger Stuewer encouraged me to develop a shorter version of the first half of the chapter for his journal *Physics in Perspective*, and in the process gave me valuable editorial advice. An anonymous referee for that journal steered me toward some resources that I had missed. I especially wish to thank Sandip Pakvasa for his very helpful comments, as a result of which I steered clear of some serious errors, and for patiently answering many questions.

My work on this project spanned many years and several phases of my career. I wish to acknowledge the friends and colleagues who have helped me, beginning at the end.

This manuscript was very nearly complete by the time I began my present position at Saint Louis University. Nevertheless, I wish to thank the SLU Department of Philosophy for finding sufficient philosophical merit in my

work to invite me to join them as a colleague, which I can only regard as a compliment.

I visited Boston University during the spring of 2001. I am grateful to the Philosophy Department there for providing a congenial work environment for me. I wish especially to thank the students in my course "The Uses of Experiment" for many stimulating discussions.

Much of this manuscript was written while I served on the faculty of Arkansas State University. The challenge of carrying out research in the midst of a busy teaching schedule and a paucity of good research materials may well have proved overwhelming. I was saved largely through the assistance of my department chair Chuck Carr in coping with the former, and by the friendly and efficient services of the interlibrary loan department at the Dean B. Ellis Library in overcoming the latter. I wish also to acknowledge the congenial intellectual environment created by my philosophical colleagues at Arkansas State, especially my friend Ron Endicott (now at North Carolina State), from whom I learned so much about philosophy.

In the summer of 1999, I participated in a National Endowment for the Humanities (NEH) seminar on induction and probability directed by Deborah Mayo at Virginia Tech. The discussions that took place during that seminar influenced my thinking in many ways. I gained a great deal from everyone in the seminar, but I especially want to thank Douglas Allchin, Prasanta Bandyopadhyay, Peter Lewis, Greg Mikkelson, Cassandra Pinnick, Dave Rudge, Dan Sloughter, and Susan Vineberg for many helpful and challenging discussions.

When I began this project as a graduate student at Johns Hopkins University, I had no idea what I was getting into. Many people provided me with valuable advice, particularly Bruce Barnett and Dave Gerdes in the Physics Department. Robert Smith gave me valuable advice on interviewing scientists. Rob Rynasiewicz served as a reader on my dissertation; his comments helped me to sharpen my thinking. More importantly, he showed me by example how to approach a historical episode in physics in a responsible and scholarly manner. Allan Franklin of the University of Colorado took an interest in my project early on and gave me helpful encouragement. He also provided me with helpful feedback as a reader for Cambridge University Press. I'm also grateful to another anonymous reader for Cambridge and an anonymous reader for Johns Hopkins University Press for their comments. I am glad for having gone through graduate school with Chuck Ward, the most amiable of philosophical companions and in many ways a kindred spirit.

I finally wish to thank two philosophers from whom I have learned much as mentors and friends. Their contributions to my thinking will be self-evident in the text that follows. When I found myself confused by the statistical concepts used in physics publications, I read some articles by Deborah

Mayo and found that some things suddenly made much more sense to me. Subsequent correspondence helped further, and Deborah saved me from much rewriting of my dissertation by giving me an advance copy of *Error and the Growth of Experimental Knowledge* while it was still in page proofs. Peter Achinstein served as my dissertation advisor. His encouragement and advice kept me clear of several dead ends. His remarkably sharp critical eye and demanding standards kept me on my toes early on. After I completed my Ph.D., he remained the vigilant advisor, constantly encouraging me to keep working. While I certainly hope that this book constitutes a contribution to philosophical understanding, it was also tremendously satisfying to be able to say "yes" when Peter asked one last time, "Is it finished yet?"

Financial assistance for my 1995 interviews with CDF and D-zero physicists came from a grant-in-aid from the Friends of the Center for History of Physics, American Institute of Physics (AIP). Recordings of my interviews are in the archives of the AIP's Niels Bohr Library, and I am grateful to Spencer Weart at the AIP for his help. Arkansas State University provided me with a faculty research assistance grant for a round of follow-up interviews in 1998. Completion of the manuscript was facilitated by a summer stipend in 2001 from the National Endowment for the Humanities. Aaron Cobb helped with the indexing.

A significant part of Chapter 1 was previously published as "Lost Origins of the Third Generation of Quarks: Theory, Philosophy, and Experiment," in *Physics in Perspective*, volume 3 (2001), 210–29. I am grateful to Birkhäuser Verlag for permission to reprint that material here. Parts of Chapter 7 have previously appeared in *Philosophy of Science*: "What Experiment Did We Just Do? Counterfactual Error Statistics and Uncertainties about the Reference Class," volume 69, 279–99, copyright 2002 by the Philosophy of Science Association, and "Novelty, Severity, and History in the Testing of Hypotheses: The Case of the Top Quark," volume 63 (Proceedings), S248–55, copyright 1996 by the Philosophy of Science Association. I am grateful to University of Chicago Press for permission to reprint material from those articles here.

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