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978-0-521-17425-1 - The Evidence for the Top Quark: Objectivity and Bias in Collaborative Experimentation

Kent W. Staley

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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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Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,
São Paulo, Delhi, Dubai, Tokyo, Mexico City

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org

Information on this title: www.cambridge.org/9780521174251

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First published 2004
First paperback edition 2011

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Staley, Kent W. (Kent Wade), 1963–
The evidence for the top quark : objectivity and bias in collaborative
experimentation / Kent W. Staley.

p. cm.

Includes bibliographical references and index.

ISBN 0-521-82710-8

1. Particles (Nuclear physics) – Flavor. 2. Quarks. 1. Title.

QC793.5.Q252S73 2004

539.7'2167–dc21 2003048465

ISBN 978-0-521-82710-2 Hardback

ISBN 978-0-521-17425-1 Paperback

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Frontmatter
[More information](#)

For Dianne

Contents

<i>Figures and Tables</i>	<i>page</i> x
<i>Preface and Acknowledgments</i>	xiii
Introduction	1
1. Origins of the Third Generation of Matter	8
1. <i>Kaons and CP Violation</i>	11
2. <i>The Standard History of the Standard Model</i>	14
3. <i>The Sakata Model and the Nagoya Model</i>	15
4. <i>Dialectical Materialism and Physical Theory</i>	19
5. <i>The X-Particle and Quartets</i>	23
6. <i>The Kobayashi and Maskawa Paper</i>	27
7. <i>The Reception of Kobayashi and Maskawa’s Paper</i>	30
8. <i>Discussion: “Dogmatism” and Thematic Commitment</i>	37
2. Building a Detector and a Collaboration to Run It	45
1. <i>Introduction</i>	45
2. <i>The Origins of CDF and Colliding Beams</i>	47
3. <i>The CDF Detector</i>	52
4. <i>A Detector Design for Uncertainty</i>	62
5. <i>Getting Realistic</i>	70
6. <i>Building the Detector – A Chronicle</i>	76
7. <i>Discussion</i>	84
3. Doing Physics: CDF Closes in on the Top	88
1. <i>Watching the Detectors: Physics Begins at CDF</i>	88
2. <i>Improving the Detector – How the SVX Was Won</i>	90
3. <i>CDF Comes of Age: The 1988–1989 Run</i>	100
4. <i>The Top Search Begins: The (Very Short) Race with UA2</i>	104
5. <i>Run Ia and the DPF Event</i>	110
6. <i>Top Search Strategies</i>	113
7. <i>Conclusion</i>	130

viii	<i>Contents</i>	
4.	Writing Up the Evidence: The Evolution of a Result	133
	1. <i>The Lepton-Photon Meeting and the Origins of the Evidence Paper</i>	134
	2. <i>The “October Massacre” and Writing the Evidence Paper</i>	139
	3. <i>The Choice of the SVX Tagging Algorithm</i>	141
	4. <i>The Excess of Tagged Z Events</i>	142
	5. <i>The SLT p_T Cut</i>	143
	6. <i>The “Pseudo $e\mu$ Event”</i>	148
	7. <i>The Role of Kinematical Evidence</i>	150
	8. <i>Double-Tagged Events and Significance: What to Count?</i>	154
	9. <i>Endless Meetings and Nonconvergent Processes</i>	156
	10. <i>Evidence for the Top Quark: The Paper</i>	160
	11. <i>Run Ia at D-zero</i>	163
	12. <i>Some Features of the Process of Producing the Evidence Paper</i>	168
	13. <i>The Research Paper: The Pursuit of Experiment by Other Means</i>	172
5.	Run Ib: “Observation” of the Top Quark and Second Thoughts about “Evidence”	175
	1. <i>Run Ib at CDF: A New Detector and a New Algorithm</i>	176
	2. <i>Another Bad October Meeting</i>	180
	3. <i>Another Competition over SVX b-Tagging</i>	182
	4. <i>The January 1995 Collaboration Meeting and the Observation Paper</i>	184
	5. <i>Observation of the Top Quark by D-zero</i>	187
	6. <i>Two Observation Papers</i>	189
	7. <i>Discussion: Detecting Bias with More Data and with Different Tests</i>	191
6.	A Model of the Experiment: Error-Statistical Evidence and the Top Quark	201
	1. <i>Procedure</i>	202
	2. <i>Representation: Models</i>	204
	3. <i>A Hierarchy of Models</i>	206
	4. <i>Reconciling the Two Perspectives</i>	211
	5. <i>A Model of CDF’s Ia Top Search Counting Experiment as a Statistical Test</i>	214
	6. <i>Error-Statistical Evidence</i>	221
	7. <i>Conclusion</i>	237
7.	Bias, Uncertainty, and Evidence	239
	1. <i>Introduction: Types of Experimental Success</i>	239
	2. <i>Predesignation and Tuning on the Signal</i>	243
	3. <i>The SLT Analysis</i>	250
	4. <i>What Experiment Did We Just Do? Bias, Tuning on the Signal, and the Reference Class</i>	260
	5. <i>After-Trial Attempts to Rescue the Experiment</i>	265
	6. <i>Objectivity, in Spite of It All</i>	274
	7. <i>Summary</i>	290

Cambridge University Press
978-0-521-17425-1 - The Evidence for the Top Quark: Objectivity and Bias in Collaborative
Experimentation
Kent W. Staley
Frontmatter
[More information](#)

<i>Contents</i>	ix
<i>Epilogue</i>	293
<i>Notes</i>	297
<i>Methodological Appendix</i>	313
<i>References</i>	317
<i>Index</i>	335

Figures and Tables

FIGURES

1.1 The particles of the standard model	page 9
1.2 Toshihide Maskawa	9
1.3 Makoto Kobayashi	10
1.4 Citations of Kobayashi and Maskawa 1973 in the <i>Physical Review</i> , 1974–80	30
1.5 Citations of Kobayashi and Maskawa 1973 in <i>Progress of Theoretical Physics</i> , 1974–80	42
2.1 A perspective view of the CDF detector	53
2.2 The central detector in the assembly hall	54
2.3 The forward half of the CDF detector shown in full elevation cross section	56
2.4 The B-zero collision hall and assembly hall	57
2.5 A one-quarter cross-sectional view of the CDF detector with upgrades for run Ia	58
2.6 The tracking systems closest to the beam pipe, including the vertex time projection chamber (“Vertex T.P.C.”) prior to the SVX upgrade	59
2.7 The tracking systems closest to the beam pipe with SVX/VTX modifications	60
2.8 Alvin Tollestrup with Joe Incandela, in 1995	66
2.9 Display of a $\bar{p}p$ collision event from the 1985 engineering run	82
3.1 The Lego plot used in tackling the problem of Texas towers	91
3.2 Schematic drawing of the SVX for run Ia	92
3.3 Schematic drawing of a lepton + jets decay of a $t\bar{t}$ pair	105
3.4 Schematic drawing of a dilepton decay of a $t\bar{t}$ pair	106
3.5 Three views of the “DPF” event: (a) shows a Lego plot, representing E_T as measured by the calorimeter, in the η - ϕ	

Figures and Tables xi

plane; (b) displays hits in the muon chambers and the central muon upgrade, as well as tracks in the central tracking chamber, in the $r\phi$ plane; (c) gives an $r\phi$ view of the SVX tracks, with a detail of the jet containing a displaced vertex; track length is proportional to p_T	111
3.6 A schematic representation in the $r\phi$ plane of an event with a secondary vertex	125
3.7 The first display of a secondary vertex based on SVX data, using the $d\phi$ algorithm	127
3.8 A cross-check of the jet-vertexing tagging algorithm	129
4.1 G. P. Yeh talking to reporters at the joint CDF/D-zero press conference, April 26, 1994	134
4.2 The G. P. plots	145
4.3 The first two pages of the Evidence paper	158
4.4 A cutaway schematic view of the D-zero detector	163
4.5 D-zero's event 417, shown in a Lego plot in the $\eta\phi$ plane	165
5.1 Members of D-zero submitting their "Observation" paper, electronically, to <i>Physical Review</i> , February 24, 1995	176
5.2 Results of coin tossing experiment	197
5.3 Statistical significance of CDF's counting experiment results, April 1994 to July 1998	198
7.1 A "bump" in the energy spectrum	244
7.2 Results from data collected during "search mode" at SPEAR	245
7.3 A closer look at $\psi(3695)$	246
7.4 Experiment A – An imaginary experiment at an electron-positron collider, selected data	246
7.5 Experiment B – An imaginary experiment at an electron-positron collider, with results shown from all data collected	247
7.6 Results of the low-mass dilepton search	257
7.7 An approximation of the probability distribution used for calculating the SLT significance in the Evidence paper	263
7.8 An imaginary probability distribution for the SLT experiment on the assumption that the SLT cuts were tuned on the signal	263

TABLES

4.1 Cuts Used to Select Central Electrons for the Lepton + Jets Search, Along with "Strict" and "Loose" Cuts Used for Central Electrons in the Dilepton Search	148
5.1 Numbers of Candidate Events and Estimated Backgrounds, Runs Ia and Ib	186
5.2 D-zero's Candidate Events in Various Search Channels from Their Observation Paper	192

Cambridge University Press
978-0-521-17425-1 - The Evidence for the Top Quark: Objectivity and Bias in Collaborative
Experimentation
Kent W. Staley
Frontmatter
[More information](#)

xii	<i>Figures and Tables</i>	
7.1	Counterfactual Significance Calculations Based on Counting Events	270
7.2	Counterfactual Significance Calculations Based on Counting Tags	271

Cambridge University Press

978-0-521-17425-1 - The Evidence for the Top Quark: Objectivity and Bias in Collaborative Experimentation

Kent W. Staley

Frontmatter

[More information](#)

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

Cambridge University Press

978-0-521-17425-1 - The Evidence for the Top Quark: Objectivity and Bias in Collaborative Experimentation

Kent W. Staley

Frontmatter

[More information](#)

xiv

Preface and Acknowledgments

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

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978-0-521-17425-1 - The Evidence for the Top Quark: Objectivity and Bias in Collaborative Experimentation

Kent W. Staley

Frontmatter

[More information](#)*Preface and Acknowledgments*

xv

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 Mikkelsen, Cassandra Pinnick, Dave Rudge, Dan Slougher, 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

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Kent W. Staley

Frontmatter

[More information](#)

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.

Thanks to my friends and family, especially Caroline and Lisa Staley, for their unfailing encouragement and support through many transitions and uncertainties. Above all, I am thankful to and for Dianne Brain.