

LIMITS ON WEAK ANNIHILATION IN INCLUSIVE
CHARMLESS SEMILEPTONIC B DECAYS

A Dissertation

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Thomas Oliver Meyer

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LIMITS ON WEAK ANNIHILATION IN INCLUSIVE CHARMLESS
SEMILEPTONIC B DECAYS

Thomas Oliver Meyer, Ph.D.

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Theoretical predictions for the weak decay $b \rightarrow u \ell \nu$ are subject to the contributions of higher-order terms that must be neglected in making practical phenomenological calculations. One such term that arises at order $(\Lambda/M_B)^3$ in the non-perturbative expansion describes “weak annihilation” (WA). While the contribution of this term to the total rate is expected to be small, it is predicted to have a non-trivial distribution across phase space, concentrated near the maximal value of q^2 . The significance of WA relative to the leading-order rate in this restricted region is thus greatly enhanced, and values for the CKM element $|V_{ub}|$ extracted from inclusive measurements of $b \rightarrow u \ell \nu$ made in the high q^2 regime are subject to a corresponding but unknown correction from WA. In this thesis, we analyze 9.7 fb^{-1} of e^+e^- collision data collected by the CLEO detector at CESR during a running period from 1990–1998. We identify $B \rightarrow X \ell \nu$ decays with high-momentum leptons and the proven technology of neutrino reconstruction, and fit the reconstructed q^2 spectrum for contributions from the dominant $b \rightarrow c \ell \nu$ background and the $b \rightarrow u \ell \nu$ signal. The signal shape includes, for the first time, a component representing the contribution of weak annihilation. We constrain the magnitude of WA relative to the total inclusive $b \rightarrow u \ell \nu$ rate and, consequently, the associated uncertainty on extracted values of $|V_{ub}|$. We find the magnitude of weak annihilation effects are not statistically significant and present limits for a series of different models of weak annihilation kinematics.

BIOGRAPHICAL SKETCH

Thomas Oliver Meyer was born the younger and heavier half of a set of twins outside the city of Chicago on May 3, 1975. He and his brother quickly developed a deep, long-lasting bond which led them, among other things, to conspire to “read” the family encyclopedia at the age of eight months, one torn page at a time. His reticence around people other than his brother eventually prompted his admission to Columbia Developmental Pre-School. Soon, although he still had difficulty counting by rote past ten, he was able to raise his hand when he needed to use the bathroom.

After two years of pre-school, Tom had learned to stop crying when separated from his brother and was ready for kindergarten on his own at nearby Willard School. Even at this tender age, he demonstrated a budding interest in marathoning by walking the mile home on one occasion, after having missed the bus. During these early years, his running included participation in the Special Olympics.

His elementary education continued at Clinton and Lords Park Schools before a family move across town brought him to Haines Junior High in St. Charles. At Haines, Tom struggled with indirect objects and algebraic proofs, but ultimately prevailed and was able to sidestep his freshman year of high school. In 1989, he joined other students from around the state at the Illinois Mathematics and Science Academy in Aurora, IL to participate in the early years of an innovative, publicly-funded residential high school. There he first encountered the fearsome “ ϵ - δ ” proof, managed to solve the notorious “stoplight dilemma” problem in his physics class, and ultimately learned how much could be accomplished in the last eighteen hours before an assignment was due. He graduated on schedule in 1992.

For his undergraduate education, Tom traveled westward to the California Institute of Technology in Pasadena, CA, where he enjoyed the aridity of the southern

California desert and the rigorous training of an intense physics program. There he met his future wife Janis Chang on move-in day, as he carried in his precious filing cabinet. He also developed a deep passion for trail-running, born on the steep, rocky trails of the Arroyo Seco behind JPL, and furthered with three years of running college cross-country and four years of track.

During the summers of these years, he transitioned from the prep counters of Burger King to the air-conditioned trailers of Fermilab, where his sandwich-wrapping skills gave way to fascination with the PAW analysis package and other particle physics marvels. In 1996, he graduated from Caltech with a B.S. in physics, with honors.

Despite having previously visited Ithaca, NY in the depths of a Siberian winter, he departed the sunny shores of California less than a month after graduation, beginning graduate study in experimental particle physics at Cornell University in the fall of 1996. Almost immediately, he became deeply involved in the prototyping, commissioning, and testing of the new CLEO III detector, a project that absorbed the first four years of his graduate work almost exclusively. In October 1999, he and Janis were married on a perfect fall day in upstate New York, and a week later, he ran his first marathon in Chicago, finishing in under three hours. He and Janis have yet to take a proper honeymoon.

In the fall of 2000, he passed his candidacy (“A”) exam and turned his attention to research on the elusive $b \rightarrow u \ell \nu$ decay under the expert guidance of Lawrence Gibbons. He gradually surrendered his many detector “care-and-feeding” responsibilities to younger, abler students, and worked to hone his ability to read others’ C++ and to say the words “inclusive charmless semileptonic B decay” ten times fast.

Finally, on a cold day in December 2004, having spent more than eight years in graduate school, run a half-dozen marathons, and overseen the demolition and

subsequent resurrection of a new house, he defended his dissertation on weak annihilation in inclusive $b \rightarrow u \ell \nu$ decay.

He plans next to head out into the world of quantitative finance and derivative securities, where his analytical, coding, and modeling skills will hopefully leverage him into a challenging and successful future.

OZYMANDIAS

I met a traveller from an antique land
Who said: 'Two vast and trunkless legs of stone
Stand in the desert. Near them, on the sand,
Half sunk, a shattered visage lies, whose frown,
And wrinkled lip, and sneer of cold command,
Tell that its sculptor well those passions read
Which yet survive, stamped on these lifeless things,
The hand that mocked them and the heart that fed.
And on the pedestal these words appear –
"My name is Ozymandias, king of kings:
Look on my works, ye Mighty, and despair!"
Nothing beside remains. Round the decay
Of that colossal wreck, boundless and bare
The lone and level sands stretch far away.'

– *Percy Bysshe Shelley* (1792-1822)

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Few people ever stay to read all of the credits that roll at the end of a movie, and I suspect far fewer will make it through the end of this section, even though it appears near the beginning of the work. However, despite the possibility of an empty theater at this point in the show, I cannot neglect the support, guidance, and occasional pleading of those that have helped make this entire production possible. Their efforts are immortalized in the mere existence of this work, even if their names are not specifically mentioned here.¹

The cast and crew, in no particular order:

The rain-or-shine core of the High Noon group: Adam Engst, John Whitman, Rick Hoebeke, Derek Dean, Tim Ingall, Bob Weathers, Geoff Hutchison, Blake Jacquot, Sergey Kiselev, Casey Carlstrom, Boris Dzikovski, Herb Engman, Jay Hubisz, John Hylas, Bruce Roebal, Charlie Fay. You've kept me sane when sometimes it seemed that in spite all of my efforts, the Ph.D. at the end of the tunnel seemed to be receding. Running trails without Tim just ahead wouldn't have been half as fun; I hope you've enjoyed our rivalry at least as much as I did. Adam's optimism and consistent performances always keep me coming back for more, especially when that includes pancakes early on a Saturday morning. Geoff and Bob helped bring back the runner in me, as well as the energetic little kid at times. Jay, Derek, Blake, and Sergey, as companions on the graduate school adventure, have helped remind me it is possible to smile and do science at the same time. Rick, Charlie, JBW, Herb: you made it clear that sometimes, yes, it's just better to be older. Even if you look younger, Bruce! And JTH—I owe what little speed I have and years of injury-free training to you; for that matter, I wouldn't have any thesis data at all without you. Go High Noon!

¹Even if only as a reader, you, too, deserve credit for accepting the rather ridiculous challenge of reading through this text.

The Finger Lakes Running Club, roadrunner logo and all. In particular: unstoppable president Lorrie Tily, who will surely brush aside any immovable wall she should find; trail master Joe Dabes, whose patience and dedication keep the trail series as hard-core as ever; and again Tim Ingall, whose unlimited energy and volunteerism keep the track and trails accessible and competitive, fun for all.

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Lawrence, who, perhaps more so than I, was tested sorely in the completion of this project, yet never gave up hope.

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Gregg and Jana Thayer; together, they represent most of what kept me in the field. Whether it was commiserating over field theory with Gregg, camping in the Adirondacks with them before the onslaught of the TQT gain change, or obscure `tar` and `cvs` arcana, their continual support (peppermint-flavored or otherwise) throughout our many years in the same cage has kept me (largely) sane. Among the lessons we learned together is that you don't *really* understand a problem until you've been burned by it at least once. Literally. (ECL chips can run extremely hot!)

Matt and Katie Shepherd: Matt proved to be the Herculean savior ready to shoulder responsibility for the entire drift chamber when I was looking for a place to set it down; at the same time, he was ready and willing to collaborate on the Brave New World of suez access to old roar data. Outside those arenas, Matt and Katie's dinners and wine-sampling sessions provided the respite we needed before getting back up to slam ourselves into the wall again. And again.

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