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Juan Pedro Ochoa-Ricoux

A Search for Muon Neutrino to Electron Neutrino Oscillations in the MINOS Experiment

Doctoral Thesis accepted by California Institute of Technology, Pasadena, California, USA

Springer
Supervisor’s Foreword

“Search for Muon Neutrino to Electron Neutrino Oscillations in the MINOS Experiment” by Juan “Pedro” Ochoa, is a tour de force that summarizes, clearly and in some depth, much of his vast body of work which has had a major impact on MINOS. The centerpiece of the thesis is the search for $\nu_\mu$ to $\nu_e$ oscillations which would indicate a non-zero mixing angle between the first and third neutrino generations $\theta_{13}$, currently the “holy grail” of neutrino physics. The optimal extraction of the $\nu_e$ oscillation signal is based on the novel “library event matching” (LEM) method which Ochoa developed and implemented together with colleagues at Caltech and at Cambridge, which improves MINOS reach for establishing an oscillation signal over any other method.

LEM will now be the basis for MINOS’ final results, and will likely keep MINOS at the forefront of this field until it completes its data taking in 2011. The LEM method has been further refined in the past year, to maximize MINOS’ reach in this domain.

Ochoa and his colleagues also developed the plan to run MINOS with a beam tuned for antineutrinos, which has recently proven to be successful, leading to a sensitive test of CPT symmetry by comparing the inter-generational mass splitting for neutrinos and antineutrinos. The results of the antineutrino oscillation analysis have provided tantalizing evidence of a possible difference, and so this most fundamental symmetry of particle physics will be further tested as MINOS doubles its antineutrino dataset within the next 12 months, and possibly sooner.

Ochoa’s in-depth, creative approach to the solution of a variety of complex experimental problems is an outstanding example for graduate students and longtime practitioners of experimental physics alike. Some of the most exciting results in this field to emerge in the near future may find their foundations in this thesis, for which Ochoa was awarded the National Prize for Youth of Mexico in 2008.

It was a great pleasure for me to take part in supervising the work in this thesis, and to contribute to Pedro’s growth as a physicist, together with my colleagues at Caltech, most notably Professor Ryan Patterson and Dr. Caius Howcroft in recent
years. I am therefore very glad that the publication of this thesis will give a wider audience the chance to appreciate and learn from Ochoa’s work.

It is important to mention that this work would not have been possible without the founding contributions to the study of neutrinos by Professors Barry Barish and Charles Peck at Caltech’s Lauritsen Lab over the last 40 years, the invention of this class of massive neutrino detector and the many contributions to the MINOS experiment by the late Dr. Doug Michael, and the strong support of the Department of Energy Office of High Energy Physics.

Pasadena, August 2010

Harvey B. Newman
There are many people to whom I am indebted and without whom this work would not have reached its fruitful completion.

First I would like to thank my advisor, Harvey B. Newman. Despite his many occupations, he always found the time to meet every week and constantly took an active interest in my progress. In addition, he always provided me with every available opportunity to benefit my work. I owe the successful completion of this part of my life and the opportunities that have opened up as a result to his constant support and guidance.

When I first started my graduate career, my knowledge of experimental neutrino physics was very limited. I was fortunate enough to have three extremely talented postdocs working with me at Caltech who were always willing to go well beyond the call of duty. Those postdocs are Chris Smith, Caius Howcroft, and Ryan Patterson. Almost everything I have learned about computer programming, particle physics, and statistics has been directly from them.

I was privileged enough to spend two years working with Doug Michael. His love for physics and his boldness when attacking problems has continued to inspire me since his tragic death in 2005. I have also been fortunate to work with very talented people at Caltech such as Alex Himmel, Mhair Orchanian and Hai Zheng. I would like to thank Leon Mualem who, along with Harvey Newman and Ryan Patterson, dedicated a lot of his time to ensure that this thesis was the best it could be.

Needless to say, the work presented here could not have been completed without the hard work of everybody in the MINOS collaboration and in the $v_e$ group in particular. The strong leadership of Mayly Sanchez and Trisha Vahle was key to the success of the analysis. It was truly a pleasure to work with such dedicated people such as Josh Boehm, Anna Holin, Greg Pawloski and Tingjun Yang. I want to thank David Jaffe for his encouragement during the work that we did together. I also want to thank Mark Thomson for his support throughout this time and for including me in the development of the $v_e$ selection described in this thesis that he originally proposed.
I could not have completed this thesis without the support of my dear wife, Carol. I am lucky to have you, and I am looking forward to many more adventures together. I am also grateful to all my friends from church for their constant encouragement and fellowship. I thank God for you, as well as for allowing me to complete this stage of my life, through which I hope to honor Him.

Last but not least, I want to thank my family in Mexico. My sister Sofia has always been a source of joy and a motivation for me to go visit as often as possible. My parents Lucia and Juan Manuel have provided me with every opportunity and have never failed to teach me about the importance of hard work and dedication through their own example. I dedicate this thesis to them.

Pasadena, October 2009

Juan Pedro Ochoa-Ricoux
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