Studies of Electroweak Interactions and Searches for New Physics Using Photonic Events with Missing Energy at the Large Electron-Positron Collider

Thesis by
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In Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

California Institute of Technology
Pasadena, California

2006
(Defended November 22, 2005)
Acknowledgments

First and foremost, I would like to thank my advisor, Professor Harvey B. Newman. Thank you, Harvey, for your guidance and support throughout my graduate career and for carefully reading my thesis, in spite of your extremely busy schedule.

I am profoundly grateful to Dr. Salvatore Mele for the time he invested in my single-photon paper and for his contributions to the analysis I am presenting here. I would also like to thank members of my paper committee, Drs. Jean-Jacques Blaising and Wes Metzger, for their valuable suggestions and advice.

This thesis would not have been complete without the contributions of many past and present L3 collaboration members. I would especially like to thank Drs. Sergey Shevchenko and Alex Shvorob for getting me started in L3 and for all the interesting conversations we had. I am deeply indebted to Dr. Alvise Favara for helping me develop my single-photon analysis and RFQ calibration algorithm. I am also very grateful to my companions in the RFQ calibration project: Dr. Renyuan Zhu at Caltech and Drs. Chris Tully, Utsawa Chaturvedi, and Lei Xia at CERN. In addition, I benefited a great deal from working with Drs. Juan Alcaraz, Stefan Ask, Michel Chemarin, Jean Fay, Dominique Duchesneau, Martin Gruenewald, Andre Holzner, John Langford, Vladimir Litvin, Luca Malgeri, Marco Musy, Sylvie Rosier, Daniel Ruschmeier, Stefano Villa, Alfons Weber, and Stephan Wynhoff.

I wish to thank Drs. Simon Blyth, Abdel Boucham, David Kirkby, and Gerhard Raven for providing me with their results and plots, and Dr. Zbigniew Was for answering my numerous questions on his Monte Carlo program. In preparing this thesis, I greatly benefited from the constructive criticisms of Mr. Tony Lee and Dr. Stephen Pappas. I also thank Professor Alan Weinstein for his comments and suggestions.

Teaching has become an important part of my life at Caltech. I am extremely grateful to Professor Frank Porter for providing me with this opportunity. I am
also grateful to Dr. Virginio de Oliveira Sannibale for showing me the ropes in the freshman lab. Finally, I would like to thank Ms. Virginia Licon and Ms. Donna Driscoll for taking care of all practical and administrative problems.

I dearly thank all of my friends from Russia, Caltech, and CERN. In particular, I thank Meiske and her family for making my stay in Pasadena an unforgettable experience. I am also grateful to Dr. N.Ya. Medvedev who took a genuine interest in my progress.

Last but certainly not least, I thank my mother. This thesis is dedicated to her.
Abstract

In this thesis I study the production of photonic events with missing energy in $e^+e^-$ collisions at the Large Electron-Positron (LEP) Collider. My analysis was based on 619 pb$^{-1}$ of data collected by the L3 detector between 1998 and 2000 at center-of-mass energies $\sqrt{s} = 189 - 208$ GeV, the highest energies ever attained in an $e^+e^-$ collider.

I selected a high-purity sample of 2,022 well-reconstructed single- and multi-photon events with missing energy. I analyzed this sample to measure the cross section of the process $e^+e^- \rightarrow \nu\bar{\nu}\gamma(\gamma)$. The average ratio of the measured to expected cross section was found to be

$$\frac{\sigma_{\nu\bar{\nu}\gamma}^{\text{meas}}}{\sigma_{\nu\bar{\nu}\gamma}^{\text{exp}}} = 0.987 \pm 0.022 \,(\text{stat}) \pm 0.010 \,(\text{syst}) \pm 0.010 \,(\text{theory}).$$

The number of light neutrino species was extracted:

$$N_\nu = 2.98 \pm 0.05 \,(\text{stat}) \pm 0.04 \,(\text{syst}),$$

and the first direct evidence for the reaction $e^+e^- \rightarrow \nu\bar{\nu}\gamma(\gamma)$ was found. The experimental errors in these results are smaller than those of comparable previous measurements. My selection results are also given in the form of tables, which can be used to test any future models involving photonic signatures at LEP.

These measurements take advantage of the unique photon detection capability of the L3 Experiment. The performance and operation of the L3 electromagnetic calorimeter is discussed in detail, with an emphasis on its calibration and monitoring. In particular, I describe a novel calibration system based on a Radiofrequency Quadrupole accelerator, which allowed me to achieve a calibration precision of 0.5%.

Reactions of the type $e^+e^- \rightarrow \gamma(\gamma) + \text{invisible particles}$ are predicted by a broad range of theories beyond the Standard Model, including Supersymmetry and models
with extra spatial dimensions and anomalous gauge-boson couplings. I found no evidence for such models and derived limits on the corresponding signal cross sections and model parameters. Among others, lower limits between 1.6 TeV and 0.66 TeV were set at the 95% confidence level on the new scale of gravity for the number of extra dimensions between 2 and 6.