Chapter 1

Introduction

Elementary particle physics is the field of physics which involves the study of the fundamental constituents of matter, and the interactions which govern their behavior. The fundamental particles interact by means of four fundamental forces: electromagnetic, weak, strong and gravitational. Of these interactions, three are now encompassed in the *Standard Model*.

The Standard Model has two sectors: electroweak and strong. The Electroweak sector unifies the electromagnetic and weak interactions. The strong interaction has its somewhat distinct place in terms of Quantum Chromodynamics (QCD). The fundamental particles of the Standard Model are quarks, leptons and gauge bosons. Quarks participate in all three interactions, while the charged leptons participate in all but the strong interaction. Neutrinos, the neutral leptons, participate only in the weak interaction.

These interactions (with the exception of gravity) are described in terms of quan-

Table 1.1: The Three Generations of Leptons and Quarks. The masses for quarks are the so-called 'constituent quark' masses. [1]

Generation	Quarks			Leptons		
		Charge	Mass		Charge	Mass
I	u	$+2/3$	~ 300 MeV	e^-	-1	0.511 MeV
	d	$-1/3$	~ 300 MeV	ν_e	0	≤ 15 eV
II	c	$+2/3$	~ 1500 MeV	μ^-	-1	105.66 MeV
	s	$-1/3$	~ 500 MeV	ν_μ	0	≤ 170 keV
III	t	$+2/3$	173.8 GeV	τ^-	-1	1777.05 MeV
	b	$-1/3$	~ 4700 MeV	ν_τ	0	≤ 18.2 MeV

tum field theories, *i.e.* in terms of the exchange of gauge bosons. To be specific, the electromagnetic interaction is described in terms of photon (γ) exchange, the weak interaction in terms of the exchange of intermediate vector bosons ($W^{\pm}, Z^0$), and the strong interaction in terms of gluon (g) exchange.

Experiment E835 at Fermilab is an experiment dedicated to the study the bound states of charmonium: the system composed of a charm quark and a charm anti-quark, bound by the strong interaction. This experiment follows in the tradition of Fermilab Experiment E760, many of whose measurements of charmonium state resonance parameters currently dominate the world averages. [2]

This dissertation is devoted to the study of several charmonium states in Experiment E835. Specifically, we address the charmonium states which decay into two photons: η_c, η_c', χ_0, and χ_2. In Chapter 2 we present a theoretical discussion of charmonium spectroscopy, in terms of the quark model and QCD. Because of the close analogy between QCD and Quantum Electrodynamics (QED), we also present certain relevant facts pertaining to QED. In Chapter 3 we discuss the study of charmonium spectroscopy from an experimental point of view.

In Chapters 4 through 6, we discuss in detail the experimental aspects of E835 at Fermilab. In Chapter 4 we describe the formation of charmonium states via antiproton-proton annihilation, as well as the experimental apparatus. In Chapter 5, we present details of the E835 data acquisition system, and in Chapter 6, the experimental identification of photons in the E835 detector.

In Chapter 7, we describe the methods we use to reduce our data sample from the trigger data set down to a final set of $\gamma\gamma$ candidate events. In Chapter 8, we present and discuss the final results for various resonance parameters of the charmonium states we have studied, compare them to those from other experiments and theoretical predictions, and draw conclusions.