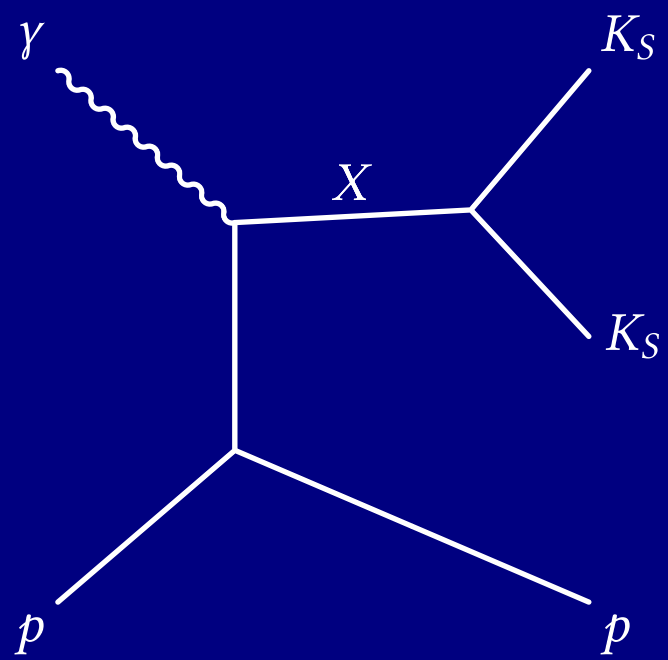
Introduction to $K_S K_S$ Physics at GlueX



Nathaniel Dene Hoffman
Carnegie Mellon University

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Chapter 1

Introduction

1.1 A Brief History of Particle Physics

Since the days of the ancient Greeks, scientists and philosophers alike have been interested in the fundamental question concerning the composition of the universe. While the Greeks maintained that the world was composed of four indivisible elemental substances (fire, earth, air, and water) [1], this was at best a guess by the early philosophers, who had no mechanism with which to test their theory. Ironically, these philosophers struggled with a question to which us modern physicists still have no answer: Are the building blocks of the natural world fundamental (indivisible) [2]?

In 1808, John Dalton published a manuscript which described what is now called the "law of multiple proportions" after compiling several observations on chemical reactions which occur with specific proportions of their reactants. He anglicized the Greek *atomos*, meaning “not able to be cut”, into the word we are familiar with—“atom” [3]. Towards the end of the century, J. J. Thomson demonstrated that cathode rays could be deflected by an electrostatic field, an observation which could not be explained by the prevailing theory that the rays were some form of light [4]. Instead, he proposed that these rays were made up of charged particles he called “corpuscles” (later renamed to the familiar “electrons”) [5]. Around the same time (between 1906 and 1913), Ernest Rutherford, Hans Geiger, and Ernest Marsden conducted experiments in which they scattered alpha particles through a thin metal foil, and, through an analysis of the scattering angles, concluded that a positively charged nucleus must exist at the center of atoms, surrounded by electrons [6].

Over the next several decades, the nucleus was further divided into protons and neutrons[1] [7, 8]. In 1964, Murray Gell-Mann and George Zweig proposed a theory that protons and neutrons (and all other baryons and mesons) were in fact composed of smaller particles Gell-Mann called “quarks”[2] [9]. These particles, along with the electron-like family of leptons (including neutrinos), the gauge bosons, and the Higgs boson, discovered in 2012 [10], comprise the Standard Model, a mathematical model which describes all the known forces and matter of the universe, with the notable exceptions (at time of writing) of gravity, dark matter, dark energy, and neutrino masses.

This thesis begins at a time when physicists are working hard to find gaps in this model, mostly by probing higher and higher ranges of energy. The experimental work being done at GlueX, however, resides in a lower regime, which we usually describe as “medium energy physics”. As I will elucidate later in this manuscript, the strong force is non-perturbative in this regime, making direct calculations through the Standard Model all but impossible. However, since the advent of Lattice Quantum Chromodynamics (LQCD) in 1974 [11], physicists have been able to make approximate predictions via computer simulations of the theory.

1.2 Thesis Overview

Herein, I will focus on a particular portion of the Standard Model that dictates the strong interaction, viz. interactions between quarks and gluons, the mediating gauge boson of the strong force. I will also utilize some aspects of the weak force in my analysis concerning the decays of kaons. I will begin with a discussion of the theory and history of K_S (K-short) pair production in prior experiments, followed by a brief overview of the GlueX experiment. I will then outline some of the theoretical underpinnings and implications of glueballs to persuade the reader on the importance of this production channel in the larger scheme of GlueX.

Next, I will describe my own analysis, beginning with the the impetus of this study, a search for Σ^+ baryons using a different recombination of the final state in this channel. This will lead to a first-order peek at the many resonances which decay to K_S pairs, and I will delineate the layers of data selection which I carried out to produce a clean sample of events.

I will then discuss the process of partial-wave analysis (PWA), modeling resonances, and selecting a waveset for my data. I will conclude with the results from fits of these models to the data, the implications of such fits, and the next steps which I or another future particle physicist might take in order to illuminate another corner of the light mesonic spectrum.

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[1] For the discovery of the electron and neutron, Thomson and James Chadwick won Nobel Prizes in Physics in 1906 and 1935, respectively. Rutherford won the 1908 Nobel Prize in Chemistry for his research in radiation. However, I want to emphasize that while I mention the “big names” here, there are many who contributed in relative obscurity.

[2] Upon reading the section of Finnegan’s Wake which Gell-Mann cites as inspiration behind the name, I found (somewhat surprisingly) that the word “quark” was originally intended to rhyme with “mark”, “ark”, “lark”, “bark”, and so on, viz. [kwɑːrk] rather than the more common [kwɔːrk]!

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