UCNA Experiment: Analysis of 2011/2012 and 2012/2013 Data Sets

DISSERTATION

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ABSTRACT OF DISSERTATION

UCNA Experiment: Analysis of 2011/2012 and 2012/2013 Data Sets

The UCNA Experiment at the Los Alamos Neutron Science Center (LANSCE) is the first measurement of the β-decay asymmetry parameter A_0 using polarized ultracold neutrons (UCN). A_0, which represents the parity-violating angular correlation between the direction of the initial neutron spin and the emitted decay electron's momentum, determines $\lambda = g_A/g_V$, the ratio of the weak axial-vector and vector coupling constants. A high-precision determination of λ is important for weak interaction physics, and when combined with the neutron lifetime it permits an extraction of the CKM matrix element V_{ud} solely from neutron decay. At LANSCE, UCN are produced in a pulsed, spallation driven solid deuterium source and then polarized via transport through a 7 T magnetic field. Their spins can then be flipped via transport through an Adiabatic Fast Passage spin flipper located in a low-field-gradient 1 T field region prior to transport to a decay storage volume situated within a 1 T solenoidal spectrometer. Electron detector packages located at each end provide for the measurement of decay electrons. Previous UCNA results (based on data collected in 2010 and earlier) were limited by systematic uncertainties, in particular those from the UCN polarization, calibration of the electron energy, and electron backscattering. This dissertation will present a background of Neutron Decay, an overview of the UCNA Experiment, followed by a detailed report on the entire analysis process for the 2011/2012 and 2012/2013 data sets.

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This work is dedicated to my parents, Cindy and John, and my soon-to-be wife, Kirstie, for their unending support. And also to Piper, my four-legged friend who keeps me sane.

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Chapter 1

Introduction to the theory of neutron β-decay

Physics travelled a long well-trodden road before arriving at theories which describe the interactions between matter. For those who may be reading this thesis either out of shear chance or simply to support me, we'll begin with a digression on the history of particle physics beginning with the discovery of sub-microscopic building blocks. Otherwise, hopefully the theories which describe the decay of the neutron will be laid out in such a way that everyone can learn something.

1.1 The history of matter

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1.2 Nuclear Theory

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1.3 A digression on Neutrons and β decay

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1.3.1 Fermi's Theory

1.3.2 Ultracold Neutrons

Chapter 2

UCNA Experiment

The UCNA Experiment is a rather mature experiment, having taken data from 2007-2013, that aims to precisely determine a value of A_0, the neutron β-decay asymmetry parameter. Here an overview of the experimental apparatus and critical components is given, as well as previous measurements of A_0 from other experiments.

2.1 Overview

Most neutrons utilized for experimental purposes possess energies upwards of (insert number here) and are what we call fast neutrons. As (insert energy spectrum figure for neutrons) figure blah shows, we define ultracold neutrons as thos which have energies on the neV scale and typical speeds of $< 8m/s$. The goal of UCNA is to produce UCN in a solid deuterium source which is fed higher energy neutrons via a spallation source at the end of an 800 MeV proton beam. These UCN are then guided towards a material trap where they can decay. During travel, the UCN pass through a series of polarizing magnets which allows the experimenter to control the spin state of the neutrons in the trap during any run. Utilizing a strong $1T$ magnetic field in the decay volume, decay electrons are guided towards detectors at either end of the

decay volume where their energy can be reconstructed. From knowledge about the initial direction and the energy of the neutron, one can construct an energy dependent asymmetry and determine a value for A_0.

2.2 Los Alamos Neutron Science Center

2.2.1 800 MeV Proton Accelerator

Blah Blah

2.2.2 Ultracold Neutron Source

Blah Blah

2.2.3 Experimental Hall

Here we highlight some of the other experiments taking place.

2.3 Experimental Setup

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2.4 Previous measurements of A_0

2.4.1 2010 UCNA Analysis

2.4.2 PERKEO

Chapter 3

UCNA Analysis

Designing an experiment and collecting the right data are non-trivial alone, but calibrating the system and analyzing the data holds the meat and bones of any trustworthy scientific result. The calibration is a beautiful combination of simulation and data manipulation which allows one to extract the energy of an event based solely on some electronic signal. Imagine a baseball pitcher throwing a fastball into a sheet, and the observer behind the sheet must determine the velocity of the ball from only seeing the impression the pitch made on the sheet. This is the task every nuclear physics experiment is faced with, only the baseball is a particle and the sheet is our detecotr system. Below we focus on the energy calibration of our apparatus.

3.1 Simulation

3.2 Gain correction and pedestal subtraction

3.3 Activated Xenon

3.3.1 Wirechamber Calibration

Blah Blah

3.3.2 Position Dependence

Blah Blah

3.3.3 Trigger Thresholds

3.4 Energy Calibration

3.4.1 Electron Conversion Sources

3.4.2 Linearity Curves

Appendix

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Vita

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Papers in Refereed Journals

1. BLAH BLAH

Papers in Refereed Conference Proceedings

1. BLAH BLAH