Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 51 (2014) 41 – 45

Physics Procedia

ESS Science Symposium on Neutron Particle Physics at Long Pulse Spallation Sources, NPPatLPS 2013

Systematic advantages of pulsed beams for measurements of correlation coefficients in neutron decay

Bastian Märkisch*

Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, D-69120 Heidelberg

Abstract

Measurements of correlation coefficients in neutron beta decay probe the structure of the weak interaction and serve to search for new physics beyond the standard model of particle physics. In this article we describe how pulsed cold neutron beams can be employed to effectively eliminate or control leading sources of systematic uncertainty. As two examples we introduce the existing instrument PERKEO III and the new instrument PERC.

Selection and peer-review under responsibility of scientific committee of NPPatLPS 2013.

Keywords: neutron beta decay; European Spallation Source; Proton Electron Radiation Channel; cold neutrons.

1. Introduction

Within the standard model of particle physics, neutron beta decay is described using three free parameters only: The Fermi coupling constant G_F which is known very precisely from muon decay, the ratio of axial-vector and vector coupling constants $\lambda=g_A/g_V$, and the element V_{ud} of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix. On the other hand, plenty of observables are available in neutron beta decay. In addition to the neutron lifetime there are angular correlation coefficients relating the spins and momenta of the participating particles, i.e. neutron, electron, proton and the anti-neutrino. These parameters are sensitive to contributions from potential physics beyond the standard model of particle physics, like scalar and tensor interactions or right-handed currents.

* Corresponding author.
E-mail address: maerkisch@physi.uni-heidelberg.de

Selection and peer-review under responsibility of scientific committee of NPPatLPS 2013.
doi:10.1016/j.phpro.2013.12.010

They also probe the unitarity of the CKM matrix in its first row. For an introduction to the current state of research, see D. Dubbers' article in this issue. In-depth information can be found e.g. in recent reviews by Dubbers and Schmidt (2012) and Abele (2009).

Worldwide, there are currently several projects with the aim to improve the accuracy of these parameters considerably. Several paths are taken to improve on previous measurements or to measure previously unmeasured observables: The UCNA (Mendenhall et al. (2013)) and UCNB experiments use ultra-cold neutrons to benefit e.g. from the 100% polarization which is possible for UCNs. The aSPECT (Simson et al. (2009)), aCorn (Wietfeldt et al. (2009)), and Nab (Počanić et al. (2009)) experiments, which share the goal to measure the electron-neutrino angular correlation coefficient a, use much more intense white cold neutron beams. The instrument PERKEO III on the other hand makes use of a pulsed cold neutron beam, see Märkisch et al. (2009). Its successor will be the instrument PERC (Proton Electron Radiation Channel) which is currently under construction at the FRM II, Garching, see Dubbers et al. (2008). Here too a pulsed beam will be used in order to suppress systematic errors.

2. Suppression of Systematic Errors in PERKEO III

The instrument PERKEO III features a longitudinal magnetic field of 150 mT in its active region of about 2 m length. The magnetic field is bent at both ends of the active region in order to separate the charged neutron decay products from the cold neutron beam. The field guides electrons as well as protons from neutron decay onto two detectors, upstream and downstream of the active volume. More details can be found in Märkisch et al. (2009) and Mest (2011).

In 2009, a pulsed neutron beam was used in a measurement of the beta asymmetry parameter A in neutron decay. Only a single pulse with a velocity spread of $\Delta v/v = 10\%$ enters the spectrometer at a time. The scheme effectively eliminates leading sources of systematic uncertainty in comparison to previous PERKEO instruments. These are:

- Edge effects of the projection of the decay electrons onto the detectors
- Background created by the neutron beam itself
- Ambient background from neighbouring instruments, cosmics etc.
- Magnetic mirror effects from the shape of the magnetic field

Below we will describe in more detail why these effects arise and how the pulsed beam structure helps to control or to eliminate them.

2.1. Edge Effect

In the pulsed beam configuration of PERKEO III only a single neutron pulse enters the spectrometer at a time. Behind a mechanical disc chopper, the neutrons fly freely through the spectrometer without touching any material. Within the active region in the center of the experiment all field lines end on the detectors and these are large enough to accommodate for the gyration of electrons and protons from neutron decay. The projection of these particles onto the detectors is therefore edge free and the solid angle coverage is truly $2 \times 2\pi$. In previous experiments, corrections due to edge effects were $\Delta A/A = -1.7(5) \times 10^{-3}$ to the error budget, see Mund et al. (2013), which no longer apply to PERKEO III.

2.2. Background

We distinguish different sources of background: signals created by the neutron beam of the experiment and background sources which are external to the instrument. External or "ambient" background can typically be measured by blocking the neutron beam and simply measuring the persisting signal in the detectors. In PERKEO III this is measured for every cycle of the chopper. After the neutron pulse has passed through the active region of the