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João Pedro Dias Rodrigues

Title pending ;_; "A Study of possible extensions of the Standard model based on multiple Higgs Models"

o júri / the jury

presidente	**Margarida Facão** Professora Auxiliar do Departamento de Física da Universidade de Aveiro
vogais	**António Morais** Investigador Pos-doc do Departamento de Física da Universidade de Aveiro
	Nuno Castro? Professor at the University of Minho. Researcher at LIP and ATLAS experiment at CERN.

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Honestamente acho que isto vai ter que ser escrito antes da entrega

Honestly this will be written in english translated poorly from above :)

Resumo

Esta parte esta em pt

Abstract

The Standard Model of particle physics has been for some time now recognized as a placeholder theory. Too many problems have been propping up over the years, such as the strong CP problem, neutrino oscillations, matter–antimatter asymmetry, the nature of dark matter and dark energy and most recently the existence of gravitational waves background ?. In response many theories have been proposed to deal with each one of these problems. However, it's important to realise that these are not independent problems and as such we must search for a way to tackle all of these. Here we propose a simple model and look into some (maybe all?) of these problems.

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Introduction

The Standard Model

1 Introduction

It is hard to question that the Standard Model (SM) is a successful approximately framework whit whom to describe the phenomenology of Particle Physics up to the largest energy scales probed by collider measurements so far. In fact, contemporary direct searches for new physics or indirect probes via e.g. flavour anomalies, have been showing an increasingly consistency with SM predictions. This is a fundamental study and we'll discuss flavour mechanism in great detail later as many interesting features stem from this.

However, it is not untrue to state that the SM also possesses its long list of Achilles heel's, aliments and dubious results leading to serious problems for physicists, this combined with several open questions that are yet to be fully understood justifies the research made in the area of high energy physics and Phenomenology. One of such weaknesses is a missing explanation of tiny neutrino masses confirmed by flavour-oscillation experiments which we will try to approach later in this dissertation .

Due to it's successes researchers have long been tempted to try to complete the SM somehow rather than erase it. In fact several mechanisms have been proposed that build upon the SM rather than replace it. We'll investigate some of these in this project.

1.1 Composition of the Standard Model

The Standard Model is composed by force carriers, the weak gauge bosons W and Z, the photon, the electromagnetic interaction messenger and the strong force mediators, the gluons, as well by matter particles, the quarks and leptons. Being that the Higgs boson is responsible for the mass generation mechanism.

Fermions are organized in three generations. Furthermore, there are 6 different types of quarks, up and down for the first generation, charm and strange for the second as well as top and bottom for the third one. Similarly, there are 6 types of leptons, the charged ones, electron, muon and tau, and the associated neutrinos, respectively represented by (u, d, c, s, t, b) while leptons as $(e, \nu_e, \mu, \nu_\mu, \tau, \nu_\tau)$

So far we have described the physical states that are often denoted as the building blocks of nature. However we have not yet explained how such states have acquired their masses and gauge quantum numbers, such as colour and electric charge. To see this, we start by noting the the SM is a gauge theory based on the group.

$$SU(3)_c \times SU(2)_L \times U(1)_Y \quad . \tag{1}$$

Fermions are half integer spin particles most of which have electrical charge (except the neutrinos). While quarks interact via the weak, electromagnetic and strong forces, the charged leptons only feel the electromagnetic and weak forces and the neutrinos are solely weakly interacting.

A physical fermion is composed of a left-handed and a right-handed part. While the former transform as $SU(2)_L$ doublets and can be written as,

$$L^i = \begin{pmatrix} \nu_{e_L} \\ e_L \end{pmatrix}, \begin{pmatrix} \nu_{\mu_L} \\ \mu_L \end{pmatrix}, \begin{pmatrix} \nu_{\tau_L} \\ \tau_L \end{pmatrix} \quad \text{and} \quad Q^i = \begin{pmatrix} u_L \\ d_L \end{pmatrix}, \begin{pmatrix} c_L \\ s_L \end{pmatrix}, \begin{pmatrix} t_L \\ b_L \end{pmatrix} \quad , \tag{2}$$

BLSM

2 Introduction and motivation for the Model 1

Now having discussed the Standard Model. We can introduce the minimal $U(1)_{B-L}$ extension of the Standard Model (B-L-SM). This is a model trough which we can explain neutrino mass generation via through a see-saw mechanism as well as model that contains two new physical particle states, specifically a new Higgs like boson and a Z′gauge Boson. Both these bosons are given mass trough the spontaneous breaking of the $U(1)_{B-L}$ symmetry. This origin for the mass of the referenced bosons means model is already very heavily constricted due to direct searches in the Large Hadron Collide (LHC).

One of the goals of this project was to investigate precisely the phenomenological status of the B-L-SM by confronting the new physics predictions with the LHC and electroweak precision data.

The name of B-L-SM stem from the addition of a unitary symmetry $U(1)_{B-L}$, as mentioned, originating from the promotion of a accidental symmetry present in the SM. Thus the Baryon number (B) minus the Lepton number (L) become a fundamental Abelian symmetry group. As a note this model is easily embedded into higher order symmetry groups like for example the SO(10) group meaning this model can be used for the study of Grand Unified Theories.

2.1 Neutrino masses

As mentioned briefly during the course of this dissertation the SM suffers from lacking a way to explain the observed neutrino masses by default. The minimal way of addressing this problem is by adding heavy Majorana type neutrinos in order to realise a seesaw mechanism. In this chapter we hope to explain how by perform the addition we could generate light neutrino states and how this addition is justified as part of a larger theory.

2.2 Electro-Weak searches

2.2.1 Oblique parameter analysis

2.2.2 The $(g-2)_\mu$ anomaly

3HDM

Conclusions