Título: THE HIGGS BOSON AND NEW PHYSICS AT THE TEV SCALE

Nombre: Barceló Aguilar, Roberto

Universidad: Universidad de Granada

Departamento: Física teórica y del cosmos

Fecha de lectura: 11/05/2012

Mención a doctor europeo: concedido

Programa de doctorado: Física y Ciencias del Espacio

Dirección:

- **Director:** Manuel Masip Mellado

Tribunal:

- **presidente:** Fernando Cornet Sánchez del Águila
- **secretario:** JOSÉ IGNACIO ILLIANA CALERO
- **vocal:** Germán Rodrigo García
- **vocal:** Maria Margarida Nesbitt Rebelo
- **vocal:** Fabio Maltoni

Descriptores:

- FISICA DE PARTICULAS
- FISICA DE ALTAS ENERGIAS
- FISICA TEORICA DE ALTAS ENERGIAS

El fichero de tesis ya ha sido incorporado al sistema

- http://0-hera.ugr.es.adrastea.ugr.es/tesisugr/20951668.pdf

Resumen: The Standard Model (SM) of particle physics, one of the greatest achievements of the 20th century, has proved to be an extraordinarily successful theory to describe the physics at colliders below the TeV scale. However, one of the most important pieces of the theory, the mechanism responsible for the electroweak (EW) symmetry breaking, has not been confirmed yet. The main objective of the Large Hadron Collider (LHC) at CERN is to reveal the nature of this mechanism, i.e., the search for the Higgs boson, the measure of its mass and couplings. The discovery of the Higgs and of possible new particles and symmetries related to the Higgs mechanism will define a new theoretical framework valid at energies above the TeV scale.

The LHC was inaugurated in 2008 and, after solving a few problems with the set-up, in 2010 it became the most powerful collider in the world, 'beating' the Fermilab Tevatron. Data from its experiments ATLAS and CMS suggest the existence of a Higgs boson of 125 GeV compatible with the one predicted by the SM. Although we are still waiting for experimental confirmation from the data collected during 2012, the mass range where it could be found is already very constrained. We are certainly living an exciting time in particle physics.

In addition, so far LHC data do not seem to indicate any new physics beyond the SM. As a consequence, neutrino masses and the existence of dark matter are the only experimental evidences currently indicating that the model must be completed. Of course, there is the formal argument known as the 'hierarchy problem', which has been the main motivation for model building during the past 30 years and that the LHC should definitively solve. Although
not at the level of discovery, there are also experimental anomalies that motivate phenomenological studies of different extensions of the SM. In particular, during the preparation of this Thesis one of these anomalies has achieved special relevance, the forward-backward asymmetry in top-pair production measured at the last stage of the Tevatron. This unexpected effect attracted the attention of the particle physics community (there are over 100 articles appeared during 2011), and it became also my main research line during the past year. But this is the
end of the story; let us start from the beginning.

When we planned my Ph.D. project in 2008, we decided that in a first phase we would analyze different extensions of the SM such as Little Higgs, Supersymmetry and Extra Dimensions. In a second stage and after the initial results from the LHC, we would focus on the phenomenology of the model that were favored by the data. However, due both to the delay in the LHC set-up and to the fact that the first observations pointed nowhere besides the SM, I had to slightly rethink the final destination of this Thesis. Thus, in this work two different parts can be distinguished. In the first one I describe some scenarios for new physics and discuss our contributions in each of them. In the second part I focus on the experimental hint of new physics that I consider most interesting, the forward-backward asymmetry in top-pair production measured at the Tevatron, analyzing in detail its possible implications at the LHC.

As it is mandatory in any Ph.D. Thesis in particle physics, I start reviewing the SM. I pay special attention to the Higgs sector and to the main motivation for this Thesis: the hierarchy problem and the need for new physics. Theoretical and experimental constraints on the Higgs boson mass are also discussed.

The second chapter is focused on Little Higgs models, in particular, on the so-called 'simplest' model. After a short review I discuss our main contribution, the possibility that the model accommodates in a consistent way a vectorlike T quark relatively light, of mass around 500 GeV. We show that this is possible by slightly changing the
'collective' symmetry breaking principle in the original model for an 'approximate' breaking principle. We find the anomalous couplings of the top quark and the Higgs boson in that scenario, and we deduce the one-loop effective potential, showing that it implies an EW symmetry breaking and a scalar mass spectrum compatible with the data.

The third chapter is dedicated to the phenomenological implications that new Higgs bosons could have in top-pair production. We study the possible effects caused by the massive scalars present in supersymmetric and Little Higgs models. After a review of the Higgs sector in supersymmetric models, we analyze the effect of these scalars on top-pair production when they are produced in the s-channel of gluon fusion. We first study the cross sections at the parton level and then we analyze proton-proton collisions at the LHC.

The last chapter is devoted to the forward-backward asymmetry in top-pair production. I start reviewing the observations and their compatibility with the SM. Then I discuss the effects of a generic massive gluon on that observable. We propose a framework with a gluon of mass below 1 TeV, with small and mostly axial-vector couplings to the light quarks and large coupling to the right-handed top quark. The key ingredient to define our 'stealth' gluon, invisible in other observables, is a very large decay width caused by new decay channels qQ, where q is a standard quark and Q a massive excitation with the same flavor. The model requires the implementation of energy-dependent widths, something that is not common in previous literature. We check that the model reproduces both the asymmetry and the top-pair invariant-mass distribution at hadron colliders, and we study the phenomenological implications of the quarks Q. We study how the new qQ channel affects current analyses of
top-pair production and of T-pair searches at the LHC. We also discuss the best strategy to detect the qQ channel at that collider. We have included three appendixes with details about the event selection and reconstruction, which are along the lines of those used by the different LHC experiments.