Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B 843 (2011) 429–454
NUCLEAR PHYSICS B
www.elsevier.com/locate/nuclphysb

Electroweak symmetry breaking from gauge/gravity duality

Lilia Anguelova

Department of Physics, University of Cincinnati, Cincinnati, OH 45221, USA

Received 18 August 2010; received in revised form 6 October 2010; accepted 8 October 2010

Available online 14 October 2010

Abstract

We use the gauge/gravity duality to study a model of walking technicolor. The latter is a phenomenologically promising framework for dynamical electroweak symmetry breaking. A traditional problem for technicolor models has been the need to address gauge theories at strong coupling. Recent developments in gauge/gravity duality provide a powerful tool for handling this problem. First, we revisit previously considered holographic models of QCD-like technicolor from D-branes. In particular, we develop analytical understanding of earlier numerical computations of the Peskin–Takeuchi S-parameter. Then we apply this method to the investigation of a model of walking technicolor, obtained by embedding D7–$\overline{\text{D7}}$ probe branes in a recently discovered type IIB background dual to walking behaviour. As a necessary step, we also show that there is an embedding of the techniflavor branes, that realizes chiral symmetry breaking. Finally, we show that the divergences that appear in the S-parameter can be removed by using holographic renormalization.

1. Introduction

Understanding electroweak symmetry breaking (EWSB), or equivalently the origin of mass, is a great challenge for phenomenology. In the Standard Model, EWSB is achieved via a fundamental scalar, the Higgs boson. Although conceptually simple, this possibility leads to well-known problems. More precisely, the masses of scalar fields are destabilized by quantum corrections and, even when stabilization is achieved via supersymmetry, there is an unnaturally large hierarchy between the electroweak and Planck scales. An appealing alternative to the Higgs boson is

E-mail address: anguella@ucmail.uc.edu.

0550-3213/$ – see front matter
doi:10.1016/j.nuclphysb.2010.10.007

provided by the possibility of dynamical chiral symmetry breaking [1]; models that explore that idea are known as technicolor models.

The original technicolor proposals were simply scaled-up versions of QCD and so were incompatible with electroweak precision measurements [2]. However, later models [3], called walking technicolor as the relevant gauge couplings run slower than in QCD, are considered phenomenologically viable; for a pedagogical recent review, see [4].[1] A common problem, though, for all kinds of technicolor models is that the relevant physics occurs at strong coupling. Therefore, a direct field theory computation of various quantities of interest is not possible and so the present experimental bounds are insufficient to distinguish between a Higgs boson and a walking technicolor sector. Here we will address this problem by using a powerful recently-developed tool for studying gauge theories at strong coupling. Namely, we will utilize the gauge/gravity duality to study a model of walking technicolor.

Holographic models of regular technicolor[2] have been considered in [6]. These authors use D-brane configurations, very similar to the one giving the holographic QCD model of Sakai and Sugimoto [7,8], in order to realize chiral symmetry breaking.[3] This is then translated to electroweak symmetry breaking via an appropriate embedding of the electroweak $SU(2) \times U(1)$ group into the techniflavor one. In this class of models one can compute the Peskin–Takeuchi S-parameter [2], that is an important electroweak observable. In [6], this computation was performed numerically. Before turning to walking technicolor, we will first revisit the above regular technicolor considerations with a more analytical approach. This will enable us to gain a better understanding of the situation. And also, it will be a useful preparation for the more involved new case.

To obtain a gravity dual of walking technicolor in the vein of [6], we need, first, a gravitational background that is dual to a walking gauge theory and, second, a U-shaped D-brane embedding as in [7], in order to achieve geometrical realization of chiral symmetry breaking. Fortunately, it was shown recently [10] that a suitable background is provided by one of the type IIB solutions found in [11]. The latter are deformations of the original Maldacena–Nunez background [12], which still arise from D5-branes wrapping an S^2. In this gravity dual of walking behaviour [10], we will consider D7–$\overline{\mathrm{D7}}$ probes and show that there is an embedding of a U-shape type a la Sakai–Sugimoto. Using this set-up as our model of walking technicolor, we will then compute the S-parameter with the methods we developed for the regular technicolor case.

In the walking case, it will turn out that the answer for the S-parameter needs to be renormalized. This is, perhaps, not surprising since the Maldacena–Nunez background has long been known to lead to divergences. The novelty, however, is that, due to recent advances [13] in the program of holographic renormalization [14], the background of interest for us can be renormalized. More importantly, we will renormalize the probe D7-brane action, that we need, by adding an appropriate counterterm. This will then enable us to extract a finite answer for the renormalized S-parameter. Our analytical result gives us interesting insights. However, a numerical prediction for the value of S is hindered by the presence of a set of constants, that can only be fixed by numerical methods. The determination of those constants is work in progress [15].

The present paper is organized as follows. In Section 2, we give a brief overview of the holographic construction of technicolor models from D-brane configurations in string theory.

[1] We should note the important role of [5] in the recent renewal of interest in walking technicolor.

[2] By ‘regular’ we mean the original QCD-like version, and not walking technicolor.

[3] We should note that there is a large amount of work on a class of holographic technicolor models (loosely) inspired by AdS/CFT [9], which however cannot be consistently embedded in string theory.