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The decay constant of the holographic techni-dilaton and the 125 GeV boson

Daniel Elander [a,*], Maurizio Piai [b]

[a] *Department of Theoretical Physics, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India*

[b] *Department of Physics, College of Science, Swansea University, Singleton Park, Swansea, Wales, UK*

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Abstract

We critically discuss the possibility that the 125 GeV boson recently discovered at the LHC is the holographic techni-dilaton, a composite state emerging from a strongly-coupled model of electroweak symmetry breaking. This composite state differs from the SM for three main reasons. Its decay constant is in general larger than the electroweak scale, hence suppressing all the couplings to standard-model particles with respect to an elementary Higgs boson, with the exception of the coupling to photons and gluons, which is expected to be larger than the standard-model equivalent.

We discuss three classes of questions. Is it possible to lower the decay constant, by changing the geometry of the holographic model? Is it possible to lower the overall scale of the strong dynamics, by modifying the way in which electroweak symmetry breaking is implemented in the holographic model? Is there a clear indication in the data that production mechanisms other than gluon–gluon fusion have been observed, disfavoring models in which the holographic techni-dilaton has a large decay constant?

We show that all of these questions are still open, given the present status of theoretical as well as phenomenological studies, and that at present the techni-dilaton hypothesis yields a fit to the data which is either as good as the elementary Higgs hypothesis, or marginally better, depending on what sets of data are used in the fit. We identify clear strategies for future work aimed at addressing these three classes of open questions.

In the process, we also compute the complete scalar spectrum of the two-scalar truncation describing the GPPZ model, as well as the decay constant of the holographic techni-dilaton in this model.

* Corresponding author.
E-mail address: daniel@theory.tifr.res.in (D. Elander).

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1. Introduction

July 4th 2012 will be remembered as one of the most important moments in the history of particle physics: the LHC experiments ATLAS and CMS announced the discovery of a new boson with mass $m_s \simeq 125$ GeV, and decay and production rates compatible with the Higgs particle of the minimal version of the Standard Model [1,2]. The next step is now to understand what is the nature of this particle, and in particular what are its interactions and its dynamical origin. A number of studies appeared fitting the data and comparing to a number of possible interpretations of the results, in terms of the elementary Higgs particle of the Standard Model, or of alternative scenarios [3–11]. All of the studies agree on the fact that the global fit is in substantial agreement with the Standard Model, given present uncertainties. But there is some tension in the data, in particular due to the fact that all the experiments see a substantial enhancement of the number of two photon events, which means that the best fit to the data would prefer a modification of some of the couplings of the putative Higgs particle, in particular the coupling to photons.

This is the very beginning of a process of precision measurements: the number of new particles produced and analyzed is small, and the error bars in the various measurements are large. There is unambiguous evidence that the new particle decays into two photons, and into two (real or virtual) Z or W bosons. All other possible decays have not been established firmly yet. Hence it is still premature to draw conclusions about the nature of the new boson. Yet, it is interesting to ask whether specific models, alternative to the minimal version of the SM, are favored or disfavored by current trends in the data, because in doing so we may identify what is the best strategy to actually test such alternatives, even from a purely theoretical viewpoint.

A particularly interesting hypothesis about electroweak symmetry breaking is that it might arise from a new, strongly-coupled interaction, a scenario that is usually referred to as Technicolor (TC) [12,13]. The most naive realizations of this idea suffer from many phenomenological drawbacks, for example with precision electroweak physics [14,15], besides the technical difficulties involved with dealing with a strongly-coupled field theory. It is widely accepted that a generic strongly-coupled model is already ruled out by indirect tests of the electroweak theory, well ahead of the direct searches at LHC. An exception is represented by models in which the strongly-coupled dynamics is qualitatively very different from QCD, and approximately scale-invariant at scales just above the electroweak one. This class of models is generally referred to as walking technicolor (WTC) [16], and it is known that the phenomenological arguments against generic TC models fail to disprove WTC models, which hence provide a viable and appealing framework for new physics.

There are two more reasons why WTC models are special. First of all, because the approximate scale invariance is spontaneously broken by the condensates appearing at the electroweak scale, it is plausible that a parametrically light composite scalar state be present in the low-energy spectrum. This is often referred to as a (techni-)dilaton, and has been the focus of a large number of studies [17–26]. In particular, it is known that if such a state exists its couplings are qualitatively very similar to those of the SM Higgs particle. The second reason why this possibility is interesting is that the strongly-coupled, quasi-conformal, multi-scale dynamics of WTC is suitable to be treated on the basis of the ideas of gauge–gravity dualities [27,28], and indeed a large number of studies in this direction has appeared in the literature [29–32].

In this paper we focus on the hypothesis that the new particle discovered at the LHC is the dilaton predicted by models inspired by gauge–gravity dualities (holography), which we refer to as the holographic techni-dilaton, and we critically discuss its properties, both from the theoretical point of view and in view of the experimental data. The aim of the paper is to highlight