Research Networking Programmes

Short Visit Grant ☐ or Exchange Visit Grant ☒

(please tick the relevant box)

Scientific Report

Scientific report (one single document in WORD or PDF file) should be submitted online within one month of the event. It should not exceed eight A4 pages.

Proposal Title: Spectra of Strong Dynamics From Holography

Application Reference N°: 4237

1) Purpose of the visit

We have an active collaboration with Prof. Nick Evans (Southampton): we recently constructed toy models where the chiral symmetry breaking, approximate scale invariance and the properties of the associated light dilaton state were analysed [1]. The main aim of my visit to Southampton in May-June 2013 was to intensify and focus the collaboration with Prof. Evans. The goal was to make progress on the ongoing work and also initiate new projects; publications were expected during or shortly after the visit.

As a natural by product, since Prof. Evans is an expert on the D3/probe-D7 models relevant for description of chiral symmetry and its breaking in gauge theories via holography, the project was also aiming to establish plausible training and mobility infrastructure to be used in mentoring doctoral students and postdoctoral researchers.

2) Description of the work carried out during the visit

The AdS/QCD models like the one presented in [2] provide a phenomenological holographic description of the QCD spectrum and are able to capture some of the elements of the theory. The simplest

model, though, does not describe the dynamics of the generation of the quark condensate, instead putting it in by hand. The decoupling of the deep infra-red from the meson physics is also put in by hand through a hard IR wall. In paper [3] we presented an extension, which includes all of this dynamics in one step. In [1] we had investigated the core dynamics for the quark condensate and the scalar meson, by relating their properties through holography to dialing the renormalization group flow of the quark anti-quark bilinear operator. We therefore started to investigate how to couple this dynamical "engine" from [2] to the AdS/QCD model to provide a wider description of the spectrum.

During my visit we wrote down to model and derived the equations relevant for the analysis of the spectrum. The computations to solve the equations of motion had to be carried out numerically, and we started to set up the Mathematica program to implement the renormalization group running, solution of the D7 profile and the meson masses and decay constants. Since one of the aims of the project was also to use the connection with Prof. Evans to establish a possible infrastructure for student training, a Ph.D. student (T. Alho) in the University of Jyväskylä was included in the collaboration. He fitted well into this project, since his doctoral research is focusing on the chiral symmetry and its breaking in the holographic setups. He is also highly skilled in numerical analysis and mathematica programming, and his contributions were imperative to proceed rapidly with the program development towards the production runs of the results which formed the core of the paper [3].

During my stay in Southampton we were therefore able to set up the model and construct the numerical codes required for the model analysis. These steps included several independent checks of all results at each stage by all collaboration members. Before the end of June we had a validated and working code, and started to produce final results. During July, after my return to Finland, we continued the collaboration and finalized the results and the paper [3] which now has appeared at the preprint server (Arxiv.org) and has been submitted to a journal for peer review.

3) Description of the main results obtained

The main results are documented in [3], which has been sent to a journal for peer review. The model is motivated, and its construction guided, by the top-down D3/D7 framework, with the additional input of the running of the anomalous dimension of the quark condensate through the AdS scalar mass. The

model was used to study the dynamics of SU(3) gauge theory with Nf quarks, and in particular the dependence of the spectrum on Nf as it was tuned towards the boundary of the conformal window.

The model successfully describes all expected features of walking gauge theories via the holographic setting. The chiral symmetry restoring transition into the conformal window displays Miransky scaling. In the walking regime the quark condensate grows relative to the decay constant of the pion and the scalar meson becomes light relative to the rest of the spectrum. The electroweak S parameter falls to zero.

When a small current quark mass is introduced into the theory, the exact chiral symmetry is lost and there is no conformal window. Instead, at large Nf the spectrum moves to a scaling behavior where all dimensionful quantities scale with an appropriate power of the current quark mass. Our holographic results reproduce the scaling obtained by other means in the literature. These results should provide a helpful guide for the interpretation of the results from lattice simulations of these theories.

In addition to publications, the project was successful also in transferring information and expertise. To concretize: the Ph.D student T. Alho from Jyväskylä University learned the basics of D3/D7 systems and their application to holographic modeling of chiral symmetry breaking in gauge theories.

4) Future collaboration with host institution (if applicable)

We are in progress of further analyses of the model in [3]. The extensions of phenomenological interest include the analysis at finite temperature and density, and different types of RG flows describing the running of the anomalous dimension of the quark bilinear. The holographic description and the resulting phase diagrams will be of interest both for ordinary strong interactions, QCD, and for applications in model building for electroweak symmetry breaking, Higgs physics and evolution of the early universe.

It is likely that the established connection with the Southampton University will be useful in future for training and mentoring of doctoral students and postdoctoral researches and their mobility as well.

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

T.Alho, N. Evans and K. Tuominen, "Dynamic AdS/QCD and the Spectrum of Walking Gauge Theories", ArXiv:1307.4896

6) Other comments (if any)

References

[1] N. Evans and K. Tuominen, Phys. Rev. D87 (2013) 086003, arXiv:1302.4553.
[2] J. Erlich, E. Katz, D. T. Son and M. Stephanov, Phys. Rev. Lett. 95 (2005), 261602, arXiv:hep-ph/0501128.
[3] T. Alho, N. Evans and K. Tuominen, arXiv:1307.4896.