Opponent's report on doctoral thesis

submitted at the Charles University in Prague

Institute of Particle and Nuclear Physics

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Thesis title: **Quantum aspects of particle physics models with extended gauge symmetries**

Study programme and branch: **Physics, Subnuclear physics**

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Context

Thesis contents

The thesis deals with the study of the minimal SO(10) Grand Unified Theory (GUT), based on the SO(10) representations 45+126+10, a well-motivated candidate theory for addressing many unsolved questions of the Standard Model (SM) of particle physics in a potentially predictive way. The first works related to this theory date back to the early 1980's, when a series of papers declared the model ruled out, following a tree-level analysis of the minimization of the SO(10) scalar potential and the associated unification constraints. Around 2009 this conclusion was turned around, based on a one-loop analysis of the scalar potential, which revealed new solutions compatible with SO(10) unification. Since then, a series of papers started to investigate the quantum nature of the minimal SO(10) potential, with the final goal to arrive to a solid prediction for the proton lifetime within an order of magnitude uncertainty.

Main results

The present thesis can be understood as the final step of the above mentioned efforts in assessing the phenomenological viability of the minimal SO(10) GUT. The first part of the thesis deals with a full-fledged study of the 45+126 part of the potential. Considering several constraints a particular symmetry breaking chain emerges as phenomenologically favored, allowing to predict a set of proton decay partial widths. In the second part of the thesis a complex 10 (required for a realistic Yukawa sector) is added to the scalar

potential and the outcome of the analysis is that the 45+126+10 model is ruled out perturbatively, due to the inability to reproduce the structure of the Standard Model Yukawa sector. This is an important and unexpected result, which closes a 40 year old endeavor.

Thesis assessment

Scientific aspects

The scientific output of the thesis is technically sound, also supported by a comprehensive publication in Phys Rev D as well as a preprint under peer-review submitted to the same journal. There are various technical challenges behind the thesis work, ranging from advanced group theory to higher-order calculations in perturbative quantum field theory, as well as an involved numerical analysis which supports the final result.

Extent, language and formal aspects

The extent of the thesis appears to be appropriate. Its main body is structured around the two projects undertaken by the researcher, while more technical details are deferred to a set of Appendices. The organization of the material and the language are also sufficiently clear.

Shortcomings, criticism

There are no shortcomings to be mentioned.

Overall assessment of the thesis

In my opinion this is an excellent doctoral thesis work, well written and with significant results at the forefront of the research in its field.

Questions to be asked/answered at the waiver

1) *Given that the 45+126+10 model is ruled out, what is the next-to-minimal field content which could be a candidate to proceed with the original program of finding a minimal, viable SO(10) model that allows to predict the proton lifetime within an order of magnitude uncertainty ?*

2) *Related to the previous question, it seems that a crucial point for the failure of the minimal model is that the Higgs doublets of 10 and 126 cannot mix with a GUT-scale VEV, since they transform differently under SU(4)_C. To overcome this point would it be sufficient to consider a 120 in place of a 10 ?*

Resumé

Given the high-quality of the research involved, I fully recommend the thesis approval.

27/08/2023, Padova

Luca Di Luzio