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Professor Dr. Jiri Andel
Vice-Dean
Faculty of Mathematics and Physics
Charles University Prague
Ke Karlovu 3, 121 16 Praha 2
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Re.: PhD thesis of Mgr. Tomas Brauner

Dear Professor Andel,

you have asked me to be a referee of the PhD thesis of Tomas Brauner, entitled

"Spontaneous Symmetry Breaking in Strong and Electroweak Interactions".

I do so with great pleasure, as this thesis is a wonderful example to demonstrate the progress made by a truly exceptional young scientist.

The main theme of the underlying thesis is spontaneous symmetry breaking (SSB). While the concepts of SSB have been well-known for many decades, this thesis demonstrates at hand of three examples that SSB has still several surprises in store for us. All examples are found within the standard model of elementary particle physics, albeit in different sectors, the first in effective hadronic theories for the strong interaction, the second in the electroweak sector, and the third in dense, cold quark matter.

After a very nice introductory chapter, Tomas embarks in Chapter 2 on a pedagogical discussion of the concept of spontaneous symmetry breaking. While the contents of this chapter are well known from textbooks, I would still like to stress that I have never seen a discussion which is of similar clarity and conciseness.

In Chapter 3, Tomas then reports on genuinely new results regarding the counting of Goldstone bosons. These results have been published in the Physical Review D, with Tomas as the sole author. The importance of the results is that they have the quality of a rigorous theorem: type-II Goldstone bosons (i.e., in this context those with a quadratic dispersion relation) must occur, if the commutator of two broken generators does not vanish. This theorem found by Tomas complements another theorem already known in the literature, namely that a vanishing commutator of two broken generators leads to type-I Goldstone bosons (i.e., in this context those with a linear dispersion law.) While Tomas discusses his theorem in the framework of a linear sigma model used as an effective theory for the strong interaction between hadrons, I expect it to be of much wider significance and applicable to all fields of physics where SSB plays a role.

In Chapter 4 Tomas gives another example of his insight and versatility and suggests an alternative mechanism for dynamical electroweak symmetry breaking. This mechanism is based on a Yukawa-type interaction between fermions, which, if sufficiently strong, can induce spontaneous electroweak symmetry breaking without the need to introduce a Higgs field. I expect these results to be of extreme importance for the upcoming experiments at the Large Hadron Collider at CERN, where the search for the Higgs particle is one of the prime scientific goals. Tomas has published his results (with Jiri Hosek as co-author) in a paper published in the Physical Review D.

Finally, Tomas discusses SSB in the context of cold, dense quark matter in Chapter 5. As already shown in the other research areas covered by his thesis, he impressively demonstrates his ability to leave mainstream directions and to explore unknown territory "off the beaten track" Tomas suggests that quark Cooper pairs could not only form in the color-antitriplet channel, but also in the color-sextet channel. The reason why this has not been investigated previously is that the quark-quark interaction is repulsive in this channel under single-gluon exchange which is the dominant interaction at asymptotically large densities. But at intermediate densities, there is certainly no argument which precludes sextet pairing. I expect the results to be of great importance for the physics of compact stellar objects, such as neutron stars. The results of this part of Tomas' research have been published in two papers, one in the Physical Review D (together with Jiri Hosek and Rudolf Sykora) and one in Modern Physics Letters A (with Tomas as sole author).

Comparing this thesis with others I had to referee over the past, I would rank it very close to the top, certainly among the best 3 %. At the University of Frankfurt where PhD theses still receive marks, I would have recommended to award it the highest grade "ausgezeichnet".

In conclusion, this thesis demonstrates beyond any doubt that Tomas Brauner is able to conduct creative scientific work, with results that have the potential for major breakthroughs in several different areas of physics.

I hope that these remarks are helpful in your judgment regarding the suitability of Tomas Brauner for receiving a doctoral degree from the Faculty of Mathematics and Physics of the Charles University Prague.

Sincerely yours,