Review Report for the doctoral Thesis of Matěj Hudec entitled "Aspects of baryon and lepton number non-conservation in the Standard model of particle physics and beyond".

The submitted thesis covers various phenomenological and theoretical aspects related to the physics of baryon and lepton number violation in the Standard Model (SM) and beyond. These topics have been very popular in the elementary particle physics community since the proposal of the Grand Unified Theories in the mid-seventies.

The first chapter introduces the (classical) global symmetries of the SM associated with the baryon and lepton numbers. The emphasis is to understand the link between the gauge symmetry and the accidental symmetries. The author presents what he named the "SU2U approach" to establish this connection. The way the chapter is presented has an interesting pedagogical value and it helps for the discussions of the following chapters. I appreciate also the various comments aimed at showing the limitations of the approach presented, this shows a critical attitude of the student.

In the second chapter, two models of quark-letpon unification are discussed. The models assume the minimal gauge group that allows to accomodate quark and leptons in the same gauge multiplets. A careful analysis of the the gauge and global symmetry is presented. The most original part is provided by the study of the scalar potential and the careful counting of the physical parameters that never appeared in the scientific literature. This chapter allows me to also comment on the bibliographical work made by the candidate. The bibliography is very comprehensive and the references are properly cited in the text. This shows that the student has read papers on various different topics and has come to understand and control the physical concepts and mathematical tools required.

The third chapter contains useful background material needed for the discussion in the following two chapters. I have only a minor comment on this part: the definition of lepton flavour violation and lepton flavour universality violation made in section 3.1 are perfectly consistent, but they do not coincide with the definitions commonly used in the literature. This could have been explained better in the thesis to avoid confusion when doing comparisons with other references.

The fourth chapter studies the possibility to accomodate the flavour anomalies in the context of the models presented in the previous chapter. In recent times, experimental results in B-physics have received a growing interest from the high energy physics community thanks to a series of experimental results hinting at possible departures from the SM predictions. The original aspect presented in the thesis is to approach the flavour anomalies problem from a top-down perspective. The author starts from well motivated models with minimal and simple structure and he explores to what extent it is possible to explain the anomalous data. This is the opposite of the bottom-up perspective, where ad-hoc fields are introduced to explain fully the anomalous data, resulting in quite complicated and baroque constructions. The candidate finds that the gauge structure is very constraining, thus obtaining interesting predictions: only the anomalous observables R_K and R_{K^*} can be ameliorated with the new physics; the relevant mediator should be a specific state with fixed quantum number (R_2), and other effects should appear in τ physics. I consider this top-down approach to be very interesting, and in my opinion the results are of very good scientific value. The only comment I have is the missing discussion of possible bounds from other low energy observables beyond the ones discussed in the thesis; for example, one could consider the impact of $\Delta F = 2$ processes on the parameters space of the models.

The contents presented in this chapter refer to two published journal articles and to the proceedings of the ICHEP2020 conference. The two published journal works are in collaboration with the student's supervisor and other collaborators; however, in the thesis it is clearly specified which are the tasks performed by the student. From the thesis, it emerges a very significative contribution to the work of the whole group.

In the last chapter, the student focuses on the phenomenology of the gauge leptoquark. This specific state received a lot of interest in recent years, and in this chapter the candidate presents an analysis including all the relevant leptonic decays of pseudoscalar mesons. The content of this chapter is not published, and it is based on a collaboration with another young scientist and without his supervisor. This is remarkable and it shows that the candidate reached already a good degree of autonomy in conducting scientific research.

The student has clearly taken a serious approach in writing the thesis, producing a structured and pedagogical manuscript. This is not often the case, and the clarity achieved shows a clear sign of the student maturity and understanding of the subject. In his thesis, the student has shown a good understanding of current ongoing questions in research in elementary particle physics, a capacity of dealing with the mathematical aspects in a precise way, and the importance of discussing the phenomenological and quantitative consequences of the theoretical investigations. Summarising, the PhD candidate has performed an insightful research and he obtained new original results in the field of high energy physics.

The doctoral thesis work has been performed at a high scientific level, and all of the important results presented in the fourth chapter are published in two papers in Physics Letters B and Physical Review D. I am also confident that the discussion of chapter 5 will appear soon in a peer-reviewed journal. The written thesis proves Matěj Hudec's ability for creative scientific working. The reviewed manuscript clearly fulfils the requirements of a Ph.D. thesis and in my opinion the student is suitable to be awarded the Ph.D. title for it.