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External referee report on the Habilitation Dissertation of Dr. Pavel Řezníček

I will base this report on the habilitation thesis and the Turnitin originality check submitted to me on February 22, 2023.

The thesis consists of six ATLAS collaboration journal publications on the measurement of the decay Bs → J/ψ ϕ and the CP violation phase ϕs, the angular analysis of the decay B → K* μ μ and the search for exotic multiquark structures in Bs π. This is complemented by two public ATLAS notes on the extrapolation of these analyses to the high luminosity phase of ATLAS, five public notes on ATLAS performance relevant to B physics and one CHEP conference proceeding paper on analysis tools for ATLAS B physics. The journal papers and all notes but one are signed by the entire ATLAS collaboration while the note on the level 1 dimuon trigger and the analysis tools is signed by a limited author list including the candidate. These public documents are preceded by seven chapters reviewing the current status of flavour anomalies and interpretations/parametrizations within effective field theories, the ATLAS detector, the analysis of B decays at ATLAS and the current status of the measurement of CP violation in Bs → J/ψ ϕ, the angular analysis of B → K* μ μ and the search for exotic states in the Bs π system. These review chapters are interesting because the journal papers obviously only convey the ATLAS perspective while here these results are put into perspective and compared to other experiments. There is also an introductory chapter that doubles as scientific CV and explains the contributions of the candidate to these results in much detail. The conclusion at the end is short and does not add additional information.

First, let me comment on the scientific significance of the Bs → J/ψ ϕ and B → K* μ μ results: In the absence of evidence for new particles beyond the Standard Model (SM) of particle physics, the high energy physics community places great hope in indirect probes for New Physics. These are deviations between precision measurements and SM precision predictions that reveal the existence of New Physics at perturbative orders and that together with cosmological constraints (hopefully!) fit into a consistent picture of physics beyond the SM. There are certain places within the SM where such anomalies are expected to occur: One would be the pattern of CP violation which is extremely constrained within the SM by the Cabibbo-Koyashi-Maskawa mechanism while new, heavy physics would naturally come with new patterns of CP violation. Another would be rare B meson decays that are forbidden at the tree level. Such decays can thus proceed only through loop diagrams and are hence a place where new, non-SM contributions are expected to be seen most easily. The study of CP violation in

Bs → J/ψ ϕ would belong to the first theme while the angular study of B → K* μ μ fits with the second stream of research. The ATLAS detector has not been optimized for B meson physics and lacks powerful particle identification. As a result, it is more difficult to perform these measurements at ATLAS and results will be less precise than those obtained at the LHCb experiment, another LHC experiment designed precisely for this kind of studies. Still, it is extremely important and scientifically relevant to perform cross-checks by independent experiments as anomalies are often mimicked by instrumental effects. Both for the CP violation parameters in Bs → J/ψ ϕ and for the angular observables (including P'5) in B → K* μ μ, ATLAS has obtained significant results that approach LHCb's precision. These measurements can be further improved in the high luminosity phase of ATLAS. I thus believe that this research is scientifically well motivated and will improve our understanding of physics beyond the Standard Model.

The search for exotic multiquark structures belongs to a different line of research: Here, we do not probe physics beyond the SM but rather try to improve our understanding of the strong interaction, in particular in the non-perturbative regime. The study included in this thesis was motivated by a positive result from the D0 experiment at Fermilab for a narrow structure in the Bs π system. This hint was followed up by ATLAS and other experiments and the D0 observation was not confirmed. Again, I believe that also this analysis is scientifically well motivated and in fact I am pleased to see that the candidate has demonstrated here a broader range of scientific interests.

Secondly, I would like to examine the personal contributions of the candidate to the aforementioned ATLAS research: He has been the principal author of the four Bs → J/ψ ϕ ATLAS journal papers included in this thesis. He contributed the core statistical tool (the unbinned maximum likelihood fitter), the evaluation of a number of systematic uncertainties and cross-checks, (toy-)Monte Carlo (MC) simulations and paper editorial work. He served as an advisor or co-supervisor of several bachelor and doctoral students of the analysis team. To the B0 → K* μ μ angular paper he contributed editorial work, evaluated several systematic uncertainties, prepared MC simulations and served as an advisor to one of the principal doctoral students of the analysis. He made direct contributions to the exotic QCD state search through the evaluation of several systematic uncertainties. He has also been the main author of the two public ATLAS notes on projections of the Bs → J/ψ ϕ and B → K* μ μ measurements to high luminosity ATLAS.

Furthermore, the candidate has worked on the measurement of the mass and the decay times of B+, B0 and Bs mesons in the context of ATLAS performance monitoring, which is documented in three notes included in this thesis. Other work includes co-authorship on a note estimating the effect of residual misalignment on the ATLAS B-physics measurements. He is a long-standing member of the B-physics trigger group, contributing to B-trigger validation, monitoring and efficiency evaluation, as well as supervising trigger-related work of several students. ATLAS work that is not documented in this thesis is his involvement within the collaboration of the ATLAS Semiconductor Tracker (SCT), a silicon strip detector, where he worked on the qualification of the SCT modules. He is also one of the principal authors of the ATLAS B-physics analysis software framework.

I can thus say that the work of the candidate within ATLAS is very broad – ranging from detector hardware to analysis software, performance and physics analysis. His contribution in particular to the study of CP violation within Bs → J/ψ ϕ can be qualified as very strong and leading. Several positions of responsibility (coordinator of the B-physics trigger group from 2012-2014, coordinator of the entire ATLAS B-physics group in 2013–2015) demonstrate his recognition within the collaboration. His appointment as ATLAS speaker at important scientific events (ICHEP 2022 and La Thuile 2016) goes in the same direction. I also note that he has represented ATLAS at dedicated B physics meetings such as the CKM (2021, 2018, 2016), Beauty (2020, 2018, 2014, 2005) and HQL (2014, 2008), confirming him to be a B physics expert within ATLAS.

Thirdly, I would like comment on the result of the Turnitin plagiarism analysis of the introductory chapters of the thesis (p. 1-58): The overall similarity index with other work (internet sources, publications and student papers) is found to be 35%, which actually seems low to me given that this part of the thesis is a review. There is no similarity with any single source exceeding 3% and throughout the text similarities appear to be randomly distributed. There is no paragraph, not even a single sentence that is copied in its entirety from a non-referenced source. Plagiarism is hence clearly not an issue here.

In summary, I can state that the material I have reviewed conveys the picture of an established physicist: Dr. Pavel Řezníček is an expert of ATLAS B physics, in particular of the Bs → J/ψ ϕ CP measurement, while maintaining interest in other physics topics as well. His ATLAS physics research is relevant and original and holds the promise of significant discovery in the future. He has also done ATLAS hardware and software work previously – something that might become relevant again towards the LHC-HL phase. He is well respected and well established within ATLAS collaboration and has demonstrated academic capabilities such as student supervision at different levels. I can thus give a positive opinion on the scientific quality of this habilitation thesis and on his physics research within the ATLAS collaboration. More generally I can state that Dr. Pavel Řezníček is a deserving candidate for the academic qualification he is seeking.

With best regards,

Christoph Schwanda
Deputy head and group leader