Challenges in Semileptonic B decays

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<span style="font-size: 12.000000pt;
font-family: 'Helvetica'">Two of the elements of the Cabibbo-Kobayasha-Maskawa (CKM) quark mixing matrix, Vub and Vcb, are extracted from semileptonic B decays. The results of the B factories, analysed in the light of the most recent theoretical calculations, are puzzling. For both |Vcb| and |Vub| the exclusive determination is about 3σ below the inclusive one. This discrepancy has survived several independent checks and could be an indication for New Physics. Fortunately, the upcoming experiment Belle-II has the potential to resolve the issue in the first few years of operation after its start in 2015.
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<span style="font-size: 12.000000pt; font-family:

'Helvetica'">The goal of the proposed workshop is to help developing a medium term strategy of analyses and calculations aimed at the resolution of the puzzle. We plan to have lattice and continuum theorists working together with experimentalists to discuss how to reshape the semileptonic analyses in view of the much larger luminosity expected at Belle-II, searching for ways to systematically validate the theoretical predictions in both exclusive and inclusive B decays. Indeed, new experimental analyses will be possible at Belle-II and we need to use the new information to verify and improve theoretical methods whenever possible.

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">The prospects of semileptonic decays at LHCb will also be considered: some of the measurements at LHCb will be complementary to those at Belle-II and might eventually play an important role if theory will be adequate. Finally, we plan to devote some time to discuss semitauonic decays, sensitive to new charged scalar bosons, whose current measurements show a ~3σ discrepancy with the Standard Model calculation.

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">The semileptonic decays of B mesons have been employed at the B factories to measure precisely the magnitude of the CKM matrix elements Vcb and Vub, which play an important role in the analysis of CP violation in the Standard Model and in the detailed verification of its flavour structure. Two complementary methods have been used, based on the study of either exclusive transitions to specific hadronic final states, or inclusive decay rates and distributions. These two approaches rely on different theoretical frameworks: the exclusive method is mostly based on lattice calculations of the relevant form factors, while the inclusive method is rooted in an Operator Product Expansion and attempts to extract the relevant non-perturbative quantities from experimental data.

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">The results of the B factories, analysed with the most recent lattice and continuum calculations, are puzzling. For both |Vcb| and |Vub| the exclusive determination is about 3σ below the inclusive one. This puzzling discrepancy has been around for a while, and has survived several independent checks. It could be an indication for New Physics, perhaps related to a right handed component of the weak current.

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">We believe that the upcoming experiment Belle-II has the potential to resolve the issue. The purpose of the proposed workshop is therefore to bring together lattice and continuum theorists as well as experimentalists in order to devise a medium term strategy that will include a new set of experimental analyses (made possible by the higher luminosity at Belle-II), and a detailed scrutiny of all theoretical systematics in the exclusive and inclusive calculations.

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">In particular, the Belle II collaboration is very interested in reshaping the semileptonic program and in learning ways to validate the theoretical calculations. Belle II will accumulate about 50 times the Belle dataset. This will allow them to employ hadronic tagging in all analyses of

semileptonic B decays, leading to a significant reduction of backgrounds and to a better control of the final state kinematics. In this way, a precise understanding of $B \to D^{*} l\nu$ *decays can be obtained and various inclusive charmless distributions can be measured. Other questions brought forward by experimentalists are signal simulations and QED corrections. *

<span style="font-size: 12.000000pt; font-family:
*'Helvetica'">Lattice QCD calculations have made important steps forward in the last decade. As far as the semileptonic form factors are concerned, the main directions of development are to extend the calculations beyond zero recoil, with sea quarks realistically incorporated (2+1 or 2+1+1 flavours). In addition, increasing computing power is pushing the lattice spacing down far enough that a new set of techniques is becoming feasible. Last, several ensembles of gauge fields now include up and down quarks of physical mass; by the time of the workshop calculations on these ensembles should become available. *

<span style="font-size: 12.000000pt; font-family:
*'Helvetica'">These developments are interesting in their own right. At the same time, the broader scope and stronger fundamentals may reconcile or clarify disagreements for form factor between heavy-quark sum rules and lattice QCD. *

<span style="font-size: 12.000000pt; font-family:
*'Helvetica'">For what concerns the OPE calculations of inclusive charmed decays, several higher order corrections have been computed in the last few years. It will be now important to identify and quantify the remaining limitations to accuracy, and to scrutinize the way the semileptonic fits are performed and the external constraints that are employed. In the case of charmless decays differential distributions will become available and will help constraining the relevant shape functions. We need new model-independent methods to incorporate this new information in the inclusive analyses and reduce the uncertainty of the theoretical predictions. *

*In the case of the exclusive semi-leptonic determination of |Vub| from $B \to \pi\, l\, \nu$, light cone sum rules have been employed to estimate the relevant form factor at low q^2, while lattice calculations are possible only at large q^2. The combination of these two methods allows us to predict the complete q^2 spectrum, which will be measured precisely at Belle-II. A thorough uncertainty analysis of the theoretical calculations will be discussed and may guide to possible tests and new experimental analyses. Semileptonic decays to vector mesons, or directly to their non-resonant decay products, open up additional analysis strategies, although the theoretical calculations seem quite challenging at the moment, especially due to the broadness of the resonances. An improved understanding of $B \to \rho\, l\, \nu$ will also constrain right handed currents in a way independent of $B \to \pi\, l\, \nu$, $B \to \tau\, \nu$, and $B \to X_u\, l\, \nu$, and benefit the study of the FCNC decay $B \to \rho\, l\, l$. *

<span style="font-size: 12.000000pt; font-family:
*'Helvetica'">Eventually, the purely leptonic $B \to \tau\, \nu$ decay is expected to be the most sensitive channel for the |Vub| determination at Belle-II. A precise measurement of |Vub| requires in this case improvements in the computation of the B decay constant. In the long term, therefore, the semileptonic results will confront those of $B \to \tau\, \nu$, with far reaching consequences for the Unitarity Triangle analyses and for the constraints on right-handed currents. This grants additional motivation to the main goal of the workshop, the better understanding of semileptonic B decays. *

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">Some exclusive semileptonic b decays can also be studied at LHCb, despite some difficulties (it is not easy to find a clean normalisation channel and the q^2 resolution is not excellent). Indeed, LHCb has the unique opportunity to study the B_c and Λ_b decays, that will not be covered by Belle II. How much these new experimental opportunities can contribute, even indirectly, to the precise determination of Vub and Vcb is an open question. The answer will also depend on the accuracy that theoretical calculations can reach for the $\Lambda_b \to \Lambda_c$, p and B_c form factors. LHCb has also very big samples of B and B_s already available, and it might be possible to study $B_s \to K(K)l\nu$ decays before Belle-II will dominate the field. Again, it is important to start assessing the potential of

these new channels together with theorists.

<span style="font-size: 12.000000pt; font-family:
'Helvetica'">Although a full understanding of B semileptonic decays for CKM parameters will be our main focus, we also plan to devote some time to semitauonic decays. These decays are, in many extensions of the standard model, more sensitive to new particles. Moreover, the current measurements show a ~3σ discrepancy with the Standard Model calculations. Much of the theoretical discussion (e.g., calculations of form factors) will overlap with the rest of the program, and we will investigate the experimental perspectives at Belle-II and LHCb.