## 1. LATTICE QCD CALCULATION OF WEAK MATRIX ELEMENTS .....

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Of the three fundamental forces described by the Standard Model of particle physics, the dynamics of the weak force are the least certain. Despite the discovery of the Higgs boson (or a Higgs-like scalar) in 2012, theorists still question whether the Standard Model description of electroweak symmetry breaking (EWSB) is complete. If there are any new particles or dynamics which play a role in EWSB, then they could alter the Standard Model description of quarks flavour interactions, the Cabibbo-Kobyashi-Maskawa (CKM) mechanism.

Due to confinement, quark decays are not measured directly by experiments. only hadron decays. Accurate QCD calculations are required in order to connect quark-level fundamental parameters to hadronic measurements. Numerical calculations using lattice gauge theory allow determination of the necessary weak matrix elements.

The aim of essays submitted with this title will be to summarize the key ingredients and consequences of a few lattice QCD calculations relevant for weak hadronic decays. Each author should choose a few related hadronic decays to consider, e.g. decays of the $K$, $D$, or $B$ meson. Alternatively one could study neutral $K$ or $B$ meson mixing. Some examples will require more discussion of the weak physics than others. With an example in mind, the author should then introduce the relevant notions from lattice gauge theory. The successful essay will:

1. Describe one or a few measurements to be studied in the essay. In some cases some substantial theoretical discussion will be required to connect the Standard Model process to the weak matrix element(s) which will be determined using lattice QCD.

2. Briefly introduce the key ideas in lattice QCD which will be relevant to the physical processes discussed. Some examples will warrant a discussion of lattice fermions and chirality, while others will require some mention of methods for heavy quarks on the lattice. It will be necessary to discuss the renormalization of the weak operator.

3. Review recent, unquenched calculations of the necessary matrix elements, including a discussion of the uncertainties.

### Relevant Courses

*Essential: Quantum Field Theory & Advanced Quantum Field Theory*
*Useful: Standard Model &, to a lesser extent, Statistical Field Theory*

## References

[1] A J Buras, Les Houches 1997 lectures, arXiv:hep-ph/9806471.
[2] C Gattringer and C B Lang, *Quantum Chromodynamics on the Lattice*, (Springer, 2010).
[3] N Christ, Lattice 2012 proceedings, arXiv:1301.4239.
[4] C Bouchard, Lattice 2014 proceedings, arXiv:1501.03204.