Projects for master's theses in particle physics

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1 Higher-spin resonances in hadronic light-by-light scattering

The anomalous magnetic moment of the muon, $(g-2)_\mu$, is one of the few observables with a tension between the Standard Model prediction and the experimental determination. In order to make firm statements about the nature of this discrepancy, the uncertainties due to hadronic effects at low energies need to be controlled. The contribution of hadronic light-by-light scattering (HLbL) is one of the dominant sources of uncertainty in the Standard Model prediction. In order to reduce this uncertainty and help to decide if the discrepancy points towards physics beyond the Standard Model, big research efforts are invested both in lattice-QCD computations and analytic calculations based on dispersion relations.

The goal of this project is to investigate the contribution of tensor mesons to $(g-2)_\mu$, in the context of a new dispersive framework for HLbL. Current estimates within hadronic models point towards a small contribution, but the estimates suffer from several shortcomings and do not enable any controlled uncertainty estimate.

2 Low-energy EFTs for physics beyond the Standard Model

Processes below the electroweak scale can be described in terms of a low-energy EFT (LEFT) that contains only the light Standard Model particles as degrees of freedom. A tower of higher-dimension effective operators describes the indirect effects of both the heavy Standard Model particles as well as of heavy physics beyond the Standard Model. At the hadronic scale of the order of a GeV, the effects of the strong interaction can no longer be described by perturbation theory. However, the dynamics of the lightest hadrons is again described in terms of an EFT, chiral perturbation theory (χPT).

The goal of this project is to systematically work out the chiral realization of all possible effects beyond the Standard Model that arise in the LEFT up to dimension six.

3 EFTs for nonlinearly realized electroweak symmetry

The most popular effective field theory (EFT) for physics beyond the Standard Model is the SMEFT, which assumes that the Higgs boson is part of an electroweak doublet as in the Standard Model. A more generic formulation is based on a nonlinear realization of electroweak symmetry, which leads to an EFT similar to chiral perturbation theory. Multiple competing groups have established their own version of such a nonlinear EFT, which mainly differ in the formulation of the power counting.

The goal of this project is to understand the different EFT formulations and perform a detailed comparison of the underlying assumptions, in order to decide if and where the different formulations lead to different predictions. In addition, the matching of the nonlinear theory to the low-energy EFT below the weak scale (LEFT) will be studied.