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Seeing Effective Field Theory of Neutron Decay through of Double Categories

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In this talk the Standard Model of the neutron decay is described by the exchange of the electroweak W boson. However, energy scales for this process ($\sim$ MeV) are well below the electroweak scale ($\sim$ 100 GeV). Consequently, the historical description within the low-energy effective field theory (EFT) is the correct physics picture for the neutron decay, on the one hand. On the other hand, expansion of the categorical point of view on many areas of mathematical physics will cause to deeper understanding of genuine features of these problems. New applications of categorical methods are

connected with new additional structures on categories. One of such structures, a double category, is considered in this talk. The double category structure is defined as generalization of the bicategory

structure. The use of EFT techniques and category-theoretical methods is not a mere reformulation of the problem. Different formulations of EFTs lead to identical mappings of one set of finite quantities (parameters of the theory) to another set of finite quantities (results of measurements, cross-sections, etc.). It means that the presence of infinities (quartic, quadratic and etc.) is formalism dependent, and thus their absence or presence should not be served as an argument for selecting this or that physical theory. This shows that the so-called technical hierarchy problem (the sensitivity of low-energy physics

to high-energy physics) depends on the formulation of quantum field theory, and, therefore, is devoid of physical meaning, at least for renormalisable theories. The EFT also provides a rigorous way to connect scales and estimate uncertainties. Moreover, EFT methods can bring new insights to the problem. In fact, by providing a simple framework to analyze hadronic correlation functions, the study of neutron decay to $\mathcal{O}(G_F\alpha)$ in Heavy Baryon Chiral Perturbation Theory (HBChPT) has uncovered a new \%-level "inner" correction to the ratio g_A/g_V of axial-vector to vector nucleon couplings, missed in previous analyses based on current algebra. The leading-order amplitude for the neutron decay is proportional to the Fermi coupling constant $\mathrm{G_F}$, which is precisely determined from the muon decay. Charged currents with quarks introduce the Cabibbo-Kobayashi-Maskawa (CKM) matrix element V_{ud} to the neutron beta decay amplitude. At low energies, the neutron decay is described by two coupling constants: the vector g_{V} and the axial-vector g_{A}. In the reference of this talk, there are presented all theoretical works rely on the precise evaluation of electroweak, quantum chromodynamics (QCD), and long-distance hadronic contributions to these coupling constants.

In the HBChPT framework for single-nucleon weak charged-current (CC) processes, the active degrees of freedom are the light leptons, photons, pions, and nucleons. The effect of both electroweak- and other hadronic-scale physics is encoded in a number of low-energy constants (LECs). The goal of this talk is to develop a matching procedure to express the relevant LECs in terms of perturbatively calculable Wilson coefficients and hadronic correlation functions that can then be estimated with non-perturbative methods, such as dispersive methods or lattice QCD. Since there are multiple thresholds, the electroweak scale $\sim M_{W,Z}$, the chiral symmetry breaking scale $\Lambda_\chi \sim m_N \sim$˜GeV, with m_N the mass of nucleon, and the pion mass, we adopt a multi-step matching strategy. The first step connects the Standard Model EFT to the low-energy effective theory (LEFT) below the weak scale, which coincides with the $V-A$ theory of weak interactions augmented by QED and QCD. This is a perturbative matching step. The second step connects the double category of LEFT to the double category of HBChPT by double category functors and involves non-perturbative physics. The third step consists of integrating out the pions, by matching the double category of HBChPT onto a double category of pionless EFT.

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