Solutions of the Flavor Problem through Effective Theories

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Introduction

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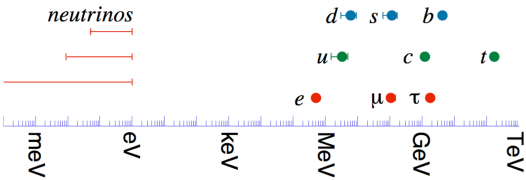
- **Neutrino Masses and Oscillations**
- **The Flavor Problem**

In the SM, flavor is accommodated by the Yukawa interactions. However, there are many parameters in this sector (masses and quark mixing matrix) which need to be extracted from exp. data.



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The solutions of these problems require physics beyond the SM. Therefore, it is fundamental to look for its effects in all possible ways:

- → **Direct production of new particles.**
- → **Precision tests in low-energy observables allowed in the SM** (e.g. $b \to s\gamma$).
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The main goal of my thesis is to exploit low-energy experimental data in order to search for New Physics (NP). Two of the projects I have worked on so far are:

1) **Impact of meson mixing on $B_s \to \phi ee$ angular observables.**[arXiv: 2210.11995]
2) **LFV in semileptonic observables at 1-loop.**[In preparation]

Motivation

Further motivation to look for NP in the flavor sector arises from hints of Lepton Flavor Universality Violation (LFUV) in $b \to s\ell\ell$ and $b \to c\ell\nu$ observables:

$$\boxed{\mathrm{R}_{\mathrm{K}^{(*)}} = \frac{\mathcal{B}(B \to K^{(*)}\mu\mu)}{\mathcal{B}(B \to K^{(*)}ee)}} \qquad \boxed{\mathrm{R}_{\mathrm{D}^{(*)}} = \frac{\mathcal{B}(B \to D^{(*)}\tau\bar{\nu})}{\mathcal{B}(B \to D^{(*)}\ell\bar{\nu})}}$$

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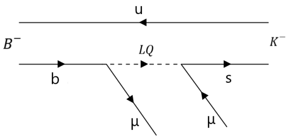

Effective Field Theories

The main tool in my research is EFTs. Heavy NP can be in general parameterized in terms of non-renormalizable operators (bottom-up approach):

$$\mathcal{L}_{\rm EFT} = \sum_i \sum_{d>4} \frac{C_i^{(d)} \mathcal{O}_i^{(d)}}{\Lambda^{d-4}} \,, \quad \Lambda = \mathcal{O}(M) \,.$$

- M : Masses of the heavy degrees of freedom (dof).
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At low-energies ($E \ll \Lambda$) the EFT can be truncated at a given order in $1/\Lambda$, depending on the accuracy at which we want to compute an observable.

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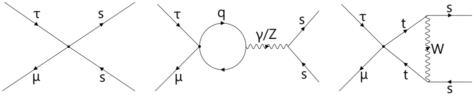

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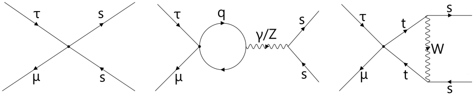

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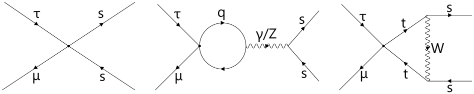

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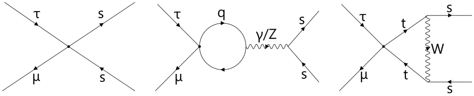

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The same pattern is observed for similar processes (e.g. $\tau \to \mu\eta$).

Project 2: New Physics in $b \to s\gamma$ transitions

R_K hints to NP in $b \to s\ell\ell$ transitions. We can also search for NP in processes related to the $b \to s\gamma$ transition, which probes the operators $\mathcal{O}_{7^{(\prime)}}$:

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There are already exp. data for $B \to K^* ee$ from LHCb [arXiv: 2010.06011] and there will be similar searches also for $B_s \to \phi ee$ in the future.

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For two of the angular observables ($A_T^{(2)}$ and $A_T^{(Im);CP}$), we find the projected constraints on the effective couplings $C_{7^{(\prime)}}$:

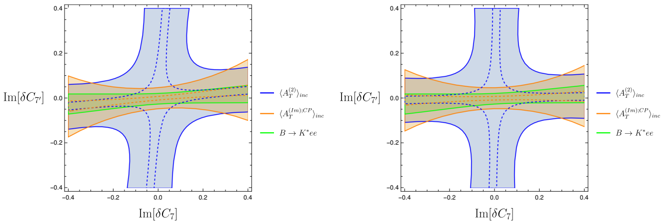

Figure 1: Constraints with mixing (left) and without mixing (right)

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Thank you!