Model-independent analysis of charged-lepton-flavour-violating τ processes

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Overview

1. D-6 Operators in the SMEFT
2. $\ell - \tau$ conversion in nuclei
3. Hadronic τ decays
4. Numerical analysis

Introduction

1. Motivation

Neutrinos oscillate, $\nu_\ell \leftrightarrow \nu_{\ell'}$: why shouldn't charged leptons?
-Minimal extensions of the SM predict negligible flavour violation in the charged lepton sector (CLFV)
-New physics scenarios allow for enhanced CLFV

Prospects:

Experiment NA64 at CERN will look for $\ell N \rightarrow \tau N'$. They claim a sensitivity of: $R_{\ell\tau} = \frac{\sigma(\ell + \mathcal{N} \rightarrow \tau + X)}{\sigma(\ell + \mathcal{N} \rightarrow \ell + X)} \sim 10^{-12} - 10^{-13}, \quad \ell = e, \mu$

Belle II will improve the limits for hadronic τ decays $\tau \rightarrow \ell hadron(s)$ at least one order of magnitude

2. Our project

Use of the SMEFT up to D-6 operators to analyse the $\tau-$involved processes

- $\ell - \tau$ conversion in nuclei:

$$\ell \; \mathcal{N}(A,Z) \quad \longrightarrow \quad \tau \; X$$

- Hadronic τ decays:

$$\begin{aligned} \tau &\rightarrow \ell P \\ \tau &\rightarrow \ell PP \qquad (\ell \neq \nu_\tau) \\ \tau &\rightarrow \ell V \end{aligned}$$

Numerical analysis with the experimental and theoretically expected limits on those decays by NA64, Belle and Belle II

Dimension-6 Operators in the SMEFT

The SMEFT framework satisfies the SM symmetries:

$$SU(3)_C \otimes SU(2)_L \otimes U(1)_Y$$

$$\mathscr{L}_{SM} = \mathscr{L}_{SM}^{(4)} + \frac{1}{\Lambda}\sum_k C_k^{(5)} \mathcal{Q}_k^{(5)} + \frac{1}{\Lambda^2}\sum_k C_k^{(6)} \mathcal{Q}_k^{(6)} + \mathcal{O}\left(\frac{1}{\Lambda^3}\right)$$

[Grzadkowski et al., 2010]

$$\Lambda \equiv \text{ Scale of NEW PHYSICS } \rightarrow \Lambda = 1\text{TeV}$$

$\ell - \tau$ conversion in nuclei

We can factorize de short-distance phenomena from the long-distance one using the factorization theorem of QCD

Perturbative part

$$\hat{\sigma}[\ell\, q_i \to \tau\, q_j] = \hat{\sigma}(C_k^{(6)})$$

Non-Perturbative part

The information of the non-perturbative part is encoded in the nuclear parton distribution functions that depend on the fraction of momenta of the nucleon carried by the quark (ξ) and the characteristic scale of the process (Q^2), $f_i(\xi, Q^2)$ [Kovařík et al., 2016]

Total cross section

The total cross section at leading order in α_s is:

$$\sigma(\ell\,\mathcal{N}(P) \to \tau\, X) = \sum_{i,j} \int_0^1 d\xi\, \{\hat{\sigma}[\ell\, q_i(\xi P) \to \tau\, q_j] f_i(\xi, Q^2) + \hat{\sigma}[\ell\, \bar{q}_j(\xi P) \to \tau\, \bar{q}_i] f_j(\xi, Q^2)\}$$

Hadronic τ decays

The perturbative cross section in terms of the Wilson coefficients from the D-6 operators is:

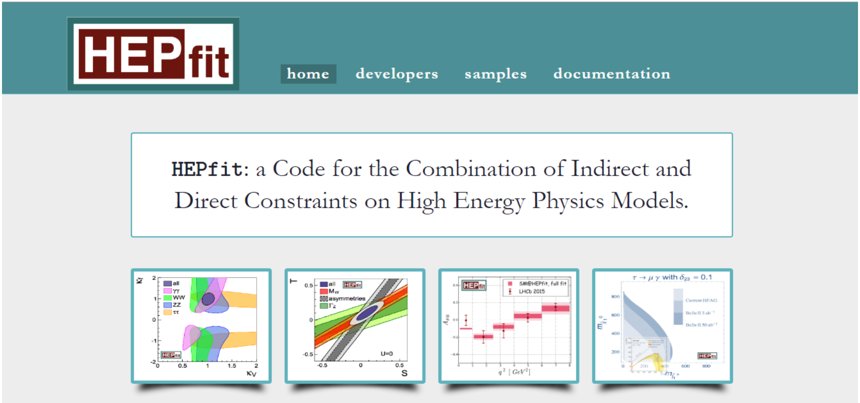
$$\hat{\sigma}[\tau \to \ell\, q_i\, q_j] = \hat{\sigma}(C_k^{(6)})$$

The quark currents are hadronized through Chiral perturbation theory (χPT) [Weinberg, 1979] and Resonance chiral theory ($R\chi T$) [Ecker et al., 1989]

We consider three different flavour violating hadronic τ decays:

1. $\tau \to \ell P: \quad P = \pi^0, K^0, \bar{K}^0, \eta, \eta'$
2. $\tau \to \ell PP: \quad PP = \pi^+\pi^-, K^0\bar{K}^0, K^+K^-, \pi^+K^-, K^+\pi^-$
3. $\tau \to \ell V: \quad V = \rho^0, \phi, \omega, K^{*0}, \bar{K}^{*0}$

Numerical analysis



http://hepfit.roma1.infn.it/

Conclusions

We performed a Model-independent analysis through the SMEFT up to D-6 operators of the whole basis of CLFV operators, then we set constraints on their Wilson coefficients

We have presented a tool for constraining the most general parameters (then also the related model-dependent ones) through CLFV$-\tau$ processes, that will become extremely useful in regards of the future experiments looking for this phenomena

Thank you very much for your attention!

http://lhcpheno.ific.uv-csic.es/

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