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

Kevin Monsálvez Pozo

IFIC, Universitat de València-CSIC

(Collaboration with Tomáš Husek and Jorge Portolés)

Overview

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

Already limits on the first and second family:
$\mu N \to eN' \;\to\; R^{Au}_{\mu e} < 7 \times 10^{-13}$ (Sindrum II, 2006)
Belle and BaBar set limits on the third family for hadronic decays:
$\tau \to \ell H(H)$ $(e.g., \Gamma_{\tau\mu\eta} < 6.5 \times 10^{-8})$

Prospects:

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

Belle II will improve the limits for hadronic τ decays $\tau \to \ell H(H)$ 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

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

[Grzadkowski et al., 2010]

$$\mathcal{Q}_{Lu} = (\bar{L}_p \gamma_\mu L_r)(\bar{u}_s \gamma^\mu u_t) \xrightarrow{CLFV} (\bar{\tau}\gamma_\mu P_L \ell)(\bar{u}_s \gamma^\mu P_R u_t)$$

$$\mathcal{Q}_{\varphi e} = (\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar{e}_p \gamma^\mu e_r) \xrightarrow{CLFV} \frac{g v^2}{2\cos\theta_W} Z_\mu (\bar{\tau}\gamma^\mu P_R \ell)$$

$\ell - \tau$ conversion in nuclei

General cross section of the process:

$$\sigma(\ell\,\mathcal{N} \to \tau\,X) = Z\,\sigma(\ell\,p \to \tau\,X) + (A - Z)\,\sigma(\ell\,n \to \tau\,X)$$

In terms of partonic cross sections at leading order in α_s:

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

$f_i(\xi)$ are the nuclear parton distribution functions

[Kovařík et al., 2016]

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

Hadronic τ decays

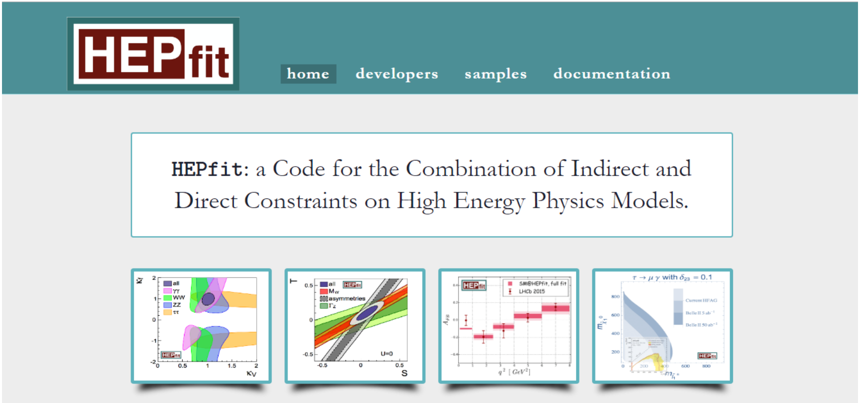
We consider three different flavour violating hadronic τ decays:

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

The quark currents in the D-6 operators are hadronized through Chiral perturbation theory (χPT) and Resonance chiral theory ($R\chi T$)
[Weinberg, 1979] [Ecker et al., 1989]

$$\mathcal{Q}_{Lu} \rightarrow (\bar{u}_s \gamma^\mu u_t) \longrightarrow \begin{cases} P & \chi PT + R\chi T \\ PP & \chi PT + R\chi T \\ V & R\chi T \end{cases}$$

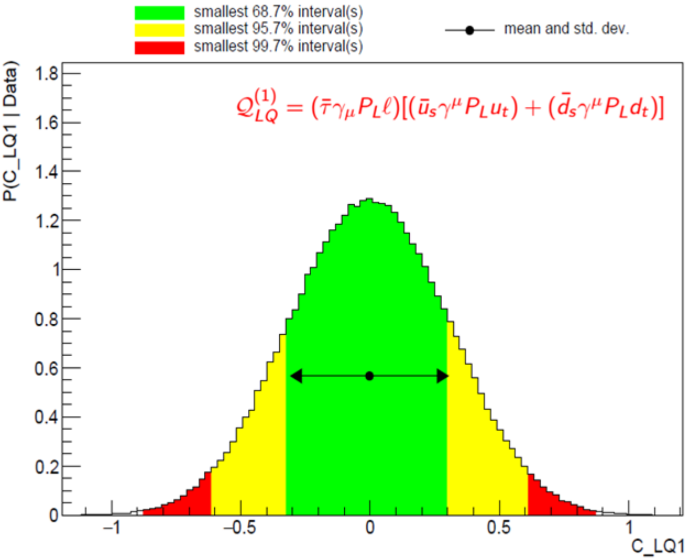
Numerical analysis



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

Results

Preliminary!



Preliminary!

$$\Lambda = 1\,TeV$$

$C_{LQ}^{(1)} = -0.002334 \pm 0.3044$

$C_{LQ}^{(3)} = 0.001823 \pm 0.5034$

$C_{eu} = 0.002215 \pm 0.519$

$C_{ed} = -0.001052 \pm 0.3232$

$C_{Lu} = 0.0129 \pm 0.828$

$C_{Ld} = 0.004037 \pm 0.5295$

$C_{Qe} = 0.001388 \pm 0.4445$

$C_{LedQ} = 0.0153 \pm 0.7735$

$C_{LeQu}^{(1)} = 0.007953 \pm 1.662$

$C_{LeQu}^{(3)} = 0.001444 \pm 0.1546$

$C_{\varphi L}^{(1)} = -0.1673 \pm 11.53$

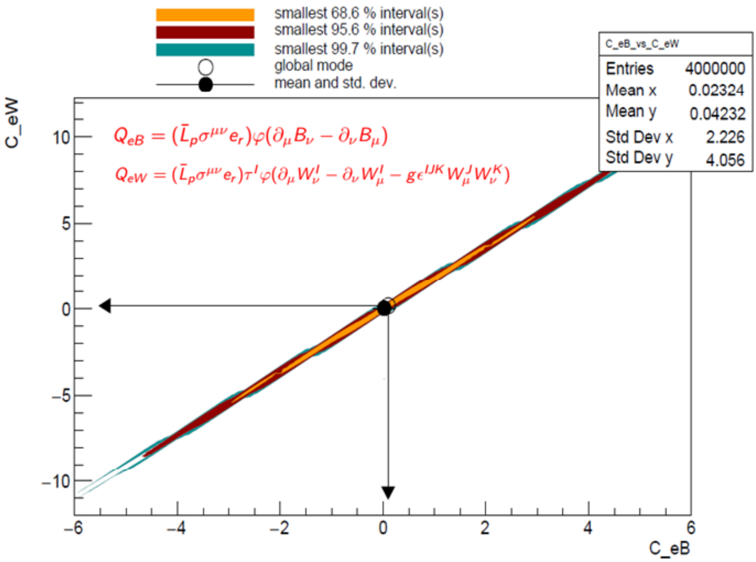
$C_{\varphi e} = 0.003808 \pm 0.6962$

$C_{\varphi L}^{(3)} = 0.1646 \pm 11.5$

$C_{eB} = 0.02324 \pm 2.226$

$C_{eW} = 0.04232 \pm 4.056$

Preliminary!



Conclusions

Future experiments will set (if not observe) stronger limits in CLFV $\tau-$ involved processes:

- NA64 $\longrightarrow \ell - \tau$ conversion in nuclei
- Belle II $\longrightarrow$ Hadronic τ decays

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

Some preliminary results have been shown

Thank you very much for your attention!

INSTITUT DE FÍSICA CORPUSCULAR

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

Bibliography

Ecker, G., Gasser, J., Pich, A., and de Rafael, E. (1989).
The Role of Resonances in Chiral Perturbation Theory.
Nucl. Phys., B321:311–342.

Grzadkowski, B., Iskrzynski, M., Misiak, M., and Rosiek, J. (2010).
Dimension-Six Terms in the Standard Model Lagrangian.
JHEP, 10:085.

Kovařík, K., Kusina, A., Ježo, T., Clark, D. B., Keppel, C., Lyonnet, F., Morfín, J. G., Olness, F. I., Owens, J. F., Schienbein, I., and Yu, J. Y. (2016).
ncteq15: Global analysis of nuclear parton distributions with uncertainties in the cteq framework.
Phys. Rev. D, 93:085037.

Weinberg, S. (1979).
Phenomenological Lagrangians.
Physica, A96(1-2):327–340.