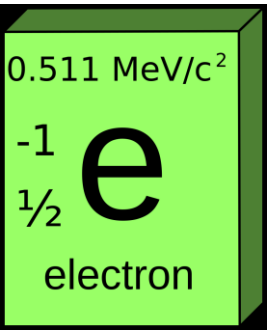
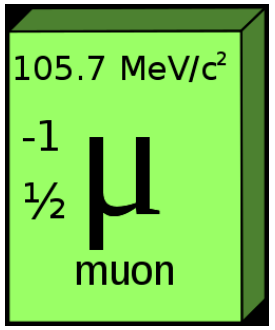
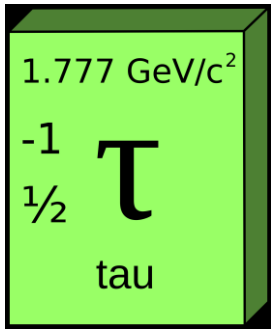
Some recent highlights in lepton Physics:







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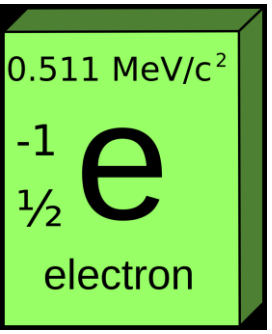
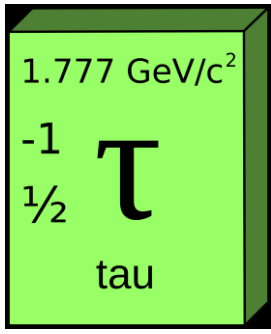
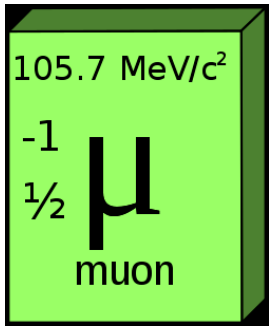
Workshop on High Energy Physics and related topics at Sonora, Mexico

18-20 August 2021 Virtual

Charged leptons Physics: Precision BSM probes







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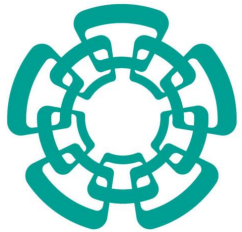

(See A. Pich's course at TAE 2018 and his several reviews on the topic available in inspires)

XVIII Mexican School of Particles & Fields

2018 University of Sonora School of High Energy Physics

21-27 October 2018 Hermosillo, Sonora

Contents

Big complementarity with Eduard's talk tomorrow!

Contents

- Motivation

- Michel parameters in presence of Majorana neutrinos (Juan Márquez Ms. Th.)

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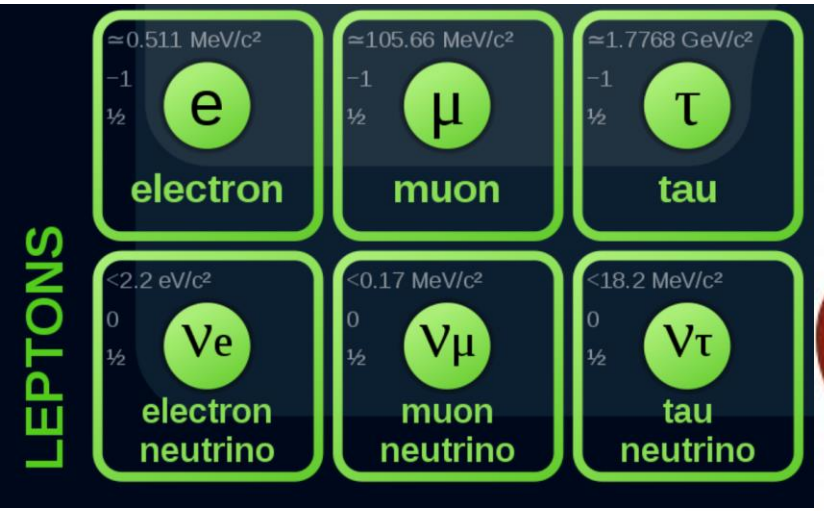
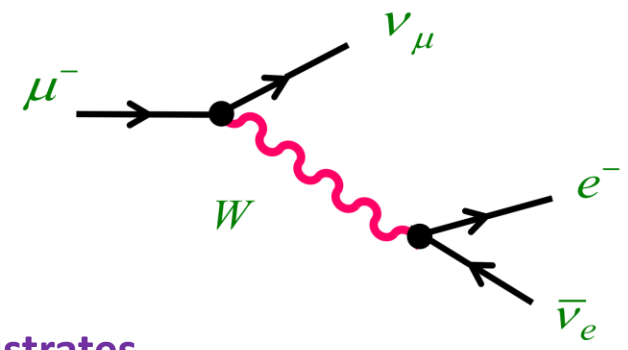
Motivation

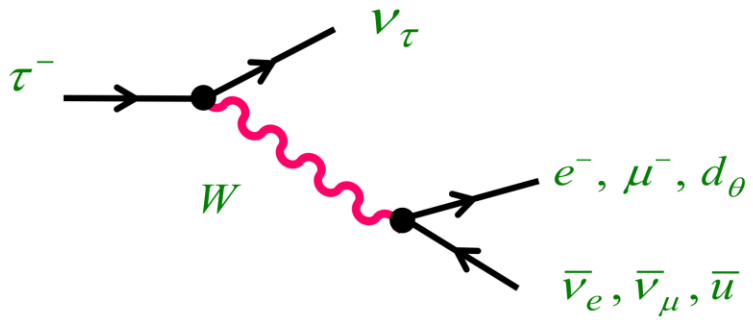


Looking for NP, go as leptonic (clean) as possible

Michel parameters in presence of Majorana neutrinos (Juan Márquez Ms. Th.)

Weak Decays





'Fundamental' Theory — Λ

This illustrates how an EFT works

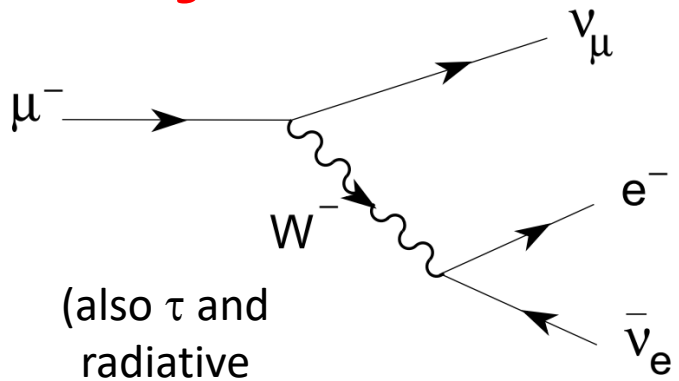
$$T(l \to \nu_l\, l' \bar{\nu}_{l'}) \sim \frac{g^2}{M_W^2 - q^2} \xrightarrow{q^2 << M_W^2} \frac{g^2}{M_W^2} = 4\sqrt{2}\, G_F$$

E — **EFT**

This dependence is fundamental for LU tests

$$\frac{1}{\tau_\mu} = \frac{G_F^2 m_\mu^5}{192\pi^3} f(m_e^2/m_\mu^2)\, r_{EW} \Rightarrow G_F = (1.166\,378\,7 \pm 0.000\,000\,6) \times 10^{-5}\ \text{GeV}^{-2}$$

Michel parameters in presence of Majorana neutrinos (Juan Márquez Ms. Th.)



(also τ and radiative decays)

$$n = S, V, T$$

$$\Gamma^S = 1,\ \Gamma^V = \gamma^\mu,\ \Gamma^T = \frac{i}{2\sqrt{2}}(\gamma^\mu\gamma^\nu - \gamma^\nu\gamma^\mu)$$

$$\mathcal{H} = 4\frac{G_{\ell'\ell}}{\sqrt{2}} \sum_{n,\epsilon,\omega} g^n_{\epsilon\omega} \left[\overline{\ell'_\epsilon}\Gamma^n(\nu_{\ell'})_\sigma\right] \left[\overline{(\nu_\ell)_\lambda}\Gamma_n\ell_\omega\right]$$

$\epsilon, \omega, \sigma, \lambda$ label the chiralities

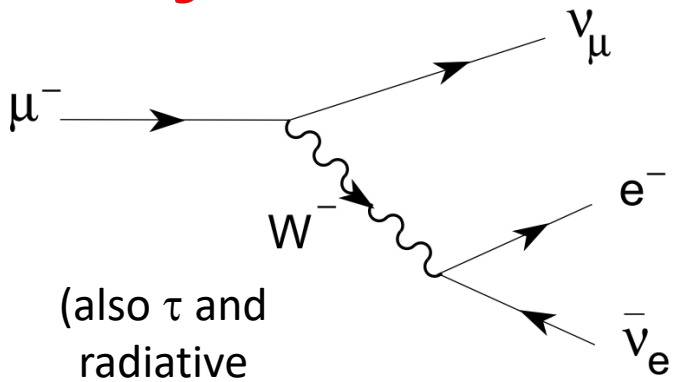
$$\frac{d^2\Gamma_{\ell\to\ell'}}{dx\, d\cos\theta} = \frac{m_\ell\,\omega^4}{2\pi^3} G^2_{\ell'\ell} \sqrt{x^2 - x_0^2} \left\{F(x) - \frac{\xi}{3}\mathcal{P}_\ell \sqrt{x^2 - x_0^2}\cos\theta\, A(x)\right\},$$

$E_{l'}^{max}$

$x \equiv E_{\ell'}/\omega$

$x_0 \equiv m_{\ell'}/\omega$

Michel parameters in presence of Majorana neutrinos (Juan Márquez Ms. Th.)



(also τ and radiative decays)

(Our) Michel parameters for L → 3l 2ν decays **not discussed today.**

This measurement will be improved at present and future experiments. Also important in several NP searches as bkg.

$\epsilon, \omega, \sigma, \lambda$ label the chiralities

$$\frac{d^2\Gamma_{\ell\to\ell'}}{dx\, d\cos\theta} = \frac{m_\ell\, \omega^4}{2\pi^3}\, G^2_{\ell'\ell}\, \sqrt{x^2 - x_0^2}\, \left\{ F(x) - \frac{\xi}{3}\, \mathcal{P}_\ell \sqrt{x^2 - x_0^2}\, \cos\theta\, A(x) \right\} ,$$

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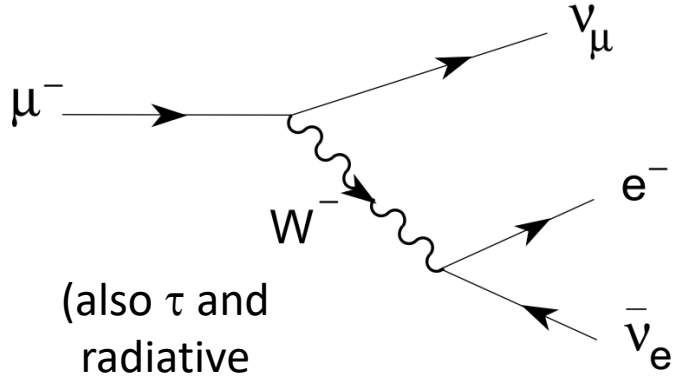

(also τ and radiative decays)

With TeV scale Majorana neutrinos, modifications to the Michel spectrum could be as large as permille effects in τ decays!!

(Our) Michel parameters for L → 3l 2ν decays **not discussed today.**

This measurement will be improved at present and future experiments. Also important in several NP searches as bkg.

$\epsilon, \omega, \sigma, \lambda$ label the chiralities

$$\frac{d^2\Gamma_{\ell\to\ell'}}{dx\, d\cos\theta} = \frac{m_\ell\, \omega^4}{2\pi^3}\, G^2_{\ell'\ell}\, \sqrt{x^2 - x_0^2}\, \left\{ F(x) - \frac{\xi}{3}\, \mathcal{P}_\ell \sqrt{x^2 - x_0^2}\, \cos\theta\, A(x) \right\} ,$$

$E_{l'}^{max}$

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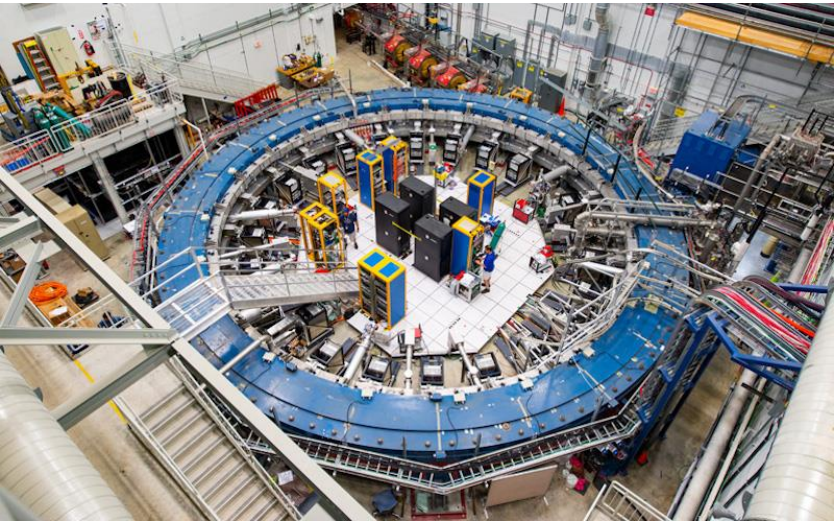
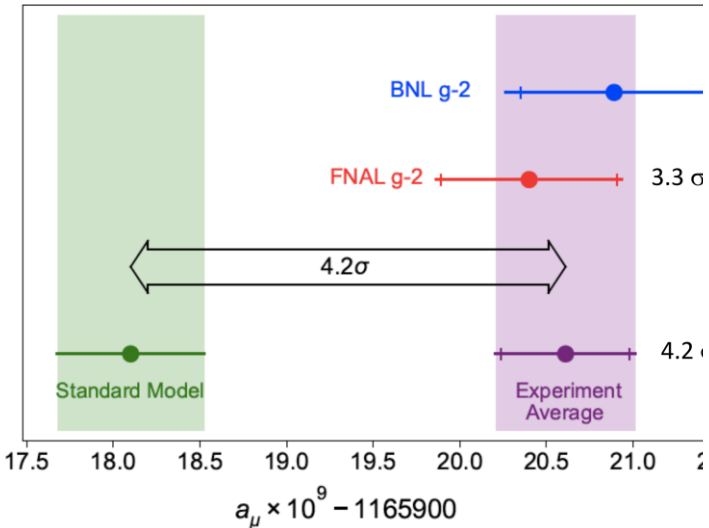
The anomalous magnetic moment of the muon (SM, Álex Miranda Ph. D. Th.)

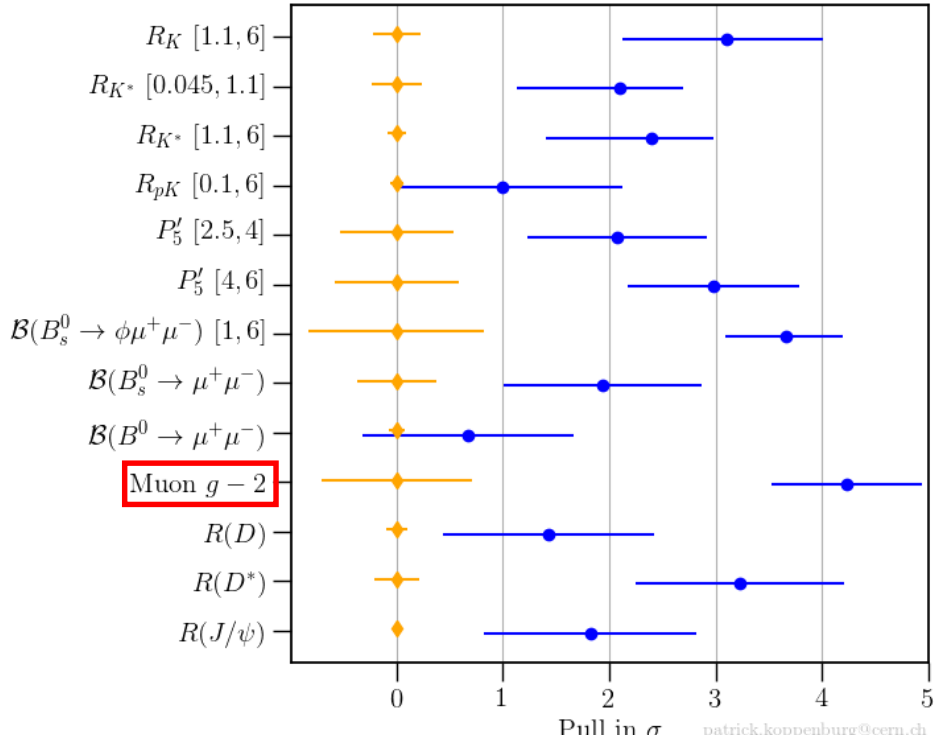
Muon g-2 Theory Initiative

https://doi.org/10.1016/j.physrep.2020.07.006 (SM prediction, '**White Paper**')

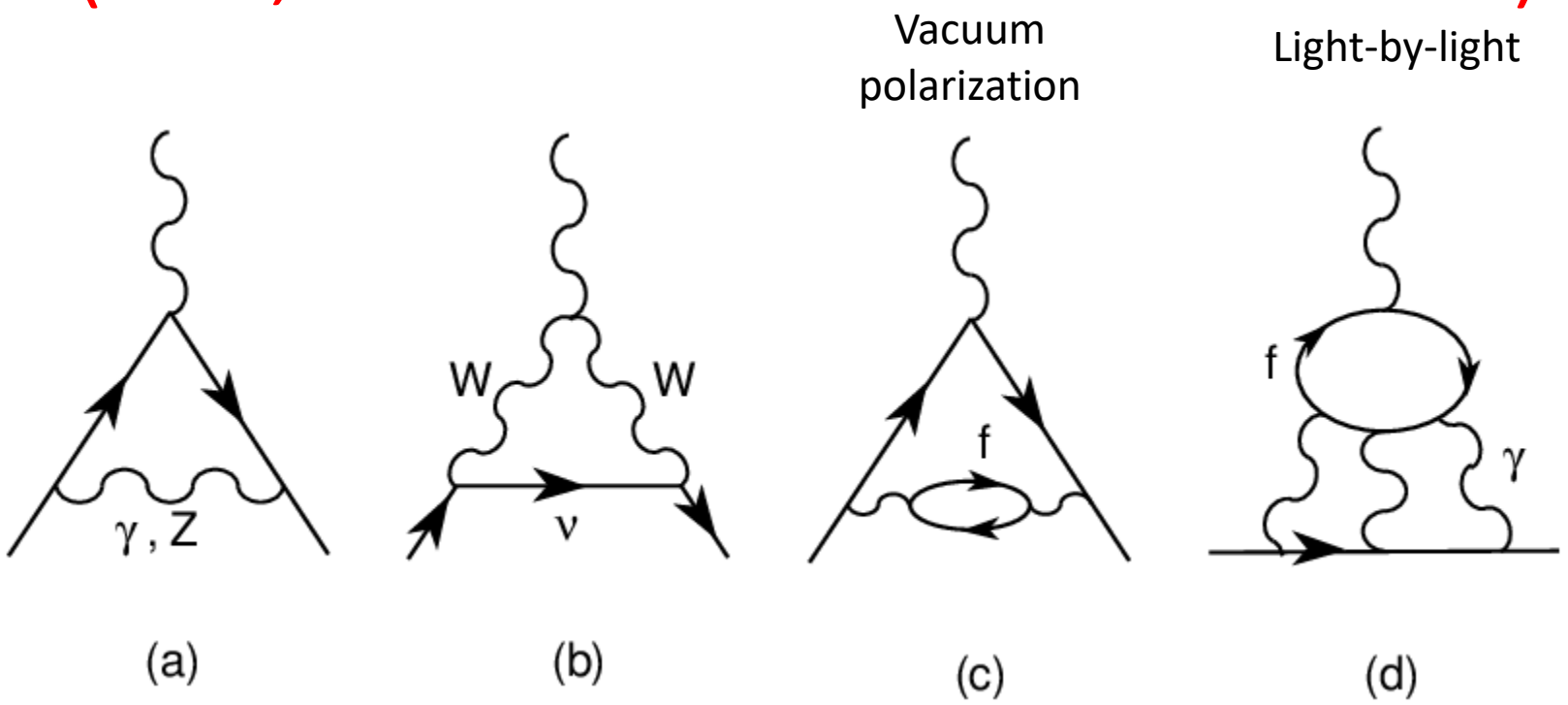
To avoid disagreement between the 'Glasgow consensus' (Prades-de Rafael-Vainshtein, *Adv.Ser.Direct.High Energy Phys.* 20 (2009) 303-317) vs. the Jegerlehner-Nyffeler number in their review, *Phys.Rept.* 477 (2009) 1-110.







The anomalous magnetic moment of the muon (SM, Álex Miranda Ph. D. Th.)



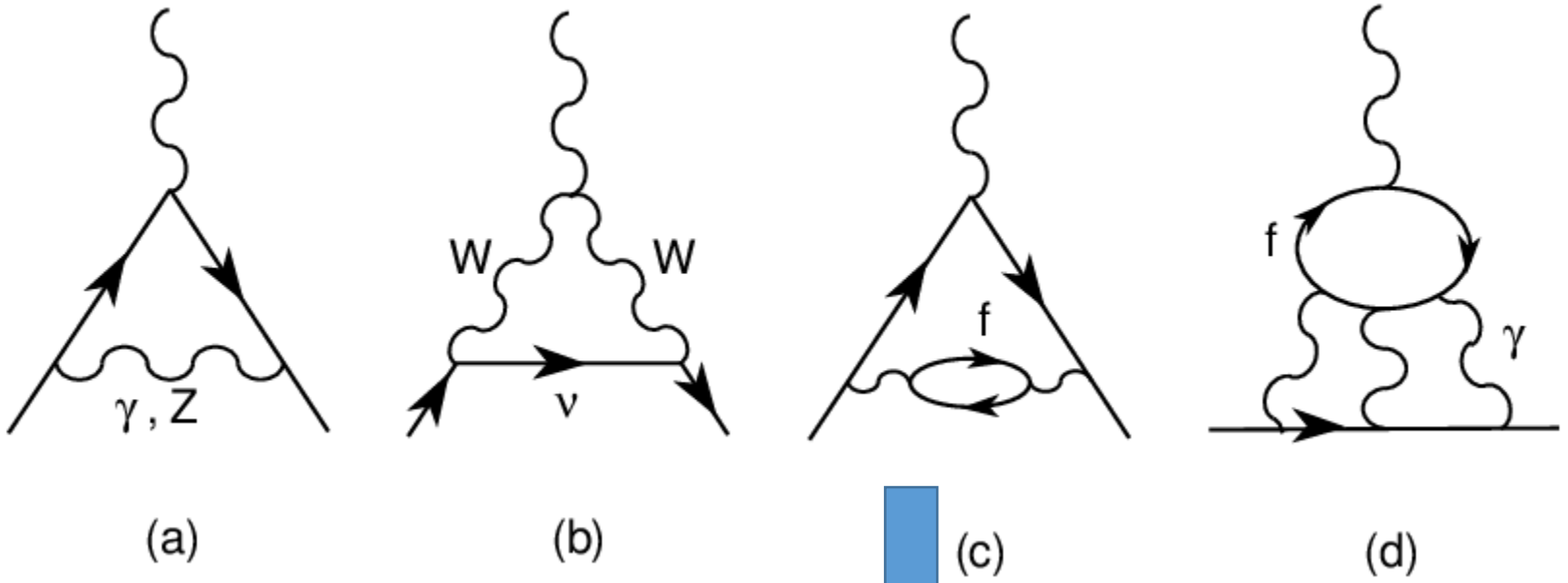
$$a_{\underset{\mu}{e}} = a_{\underset{\mu}{e}}(\mathrm{QED}) + a_{\underset{\mu}{e}}(\mathrm{hadronic}) + a_{\underset{\mu}{e}}(\mathrm{electroweak}),$$

$\vec{\mu}_l = g_l\, e/(2\, m_l)\, \vec{S}_l$, $\quad g_l = 2\,(1+a_l)$, $\quad a_l = \alpha/(2\,\pi)+\ldots$

The anomalous magnetic moment of the muon (SM, Álex Miranda Ph. D. Th.)

Vacuum polarization

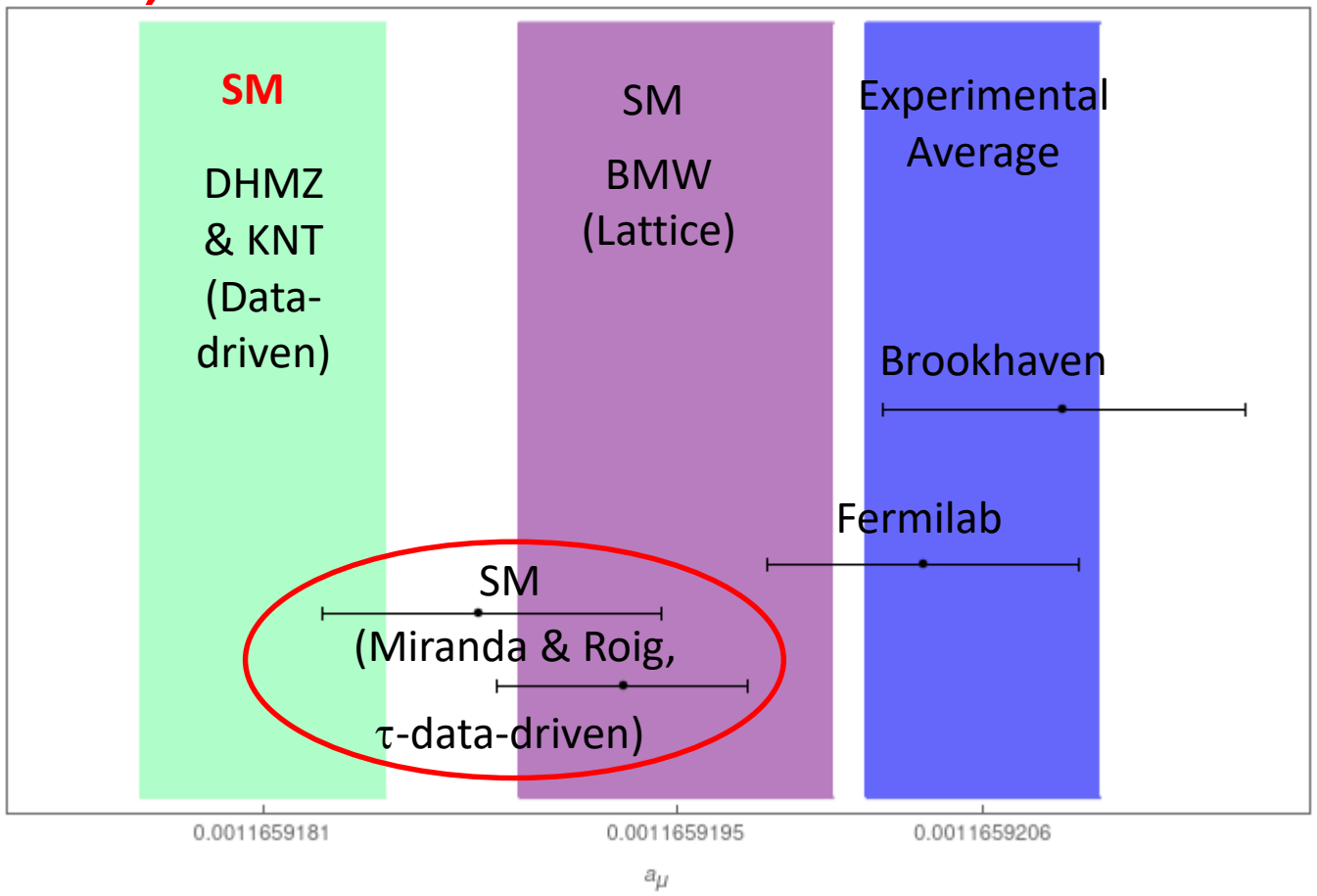
Light-by-light



Álex has focused on the dominant piece of this contribution, evaluated from $\tau \rightarrow$hadrons ν_τ data (instead of $e^+e^- \rightarrow$ hadrons data), which required computing isospin corrections beyond previous literature.

Our contributions to HLbL (RChT, DSE) **not discussed today.**

The anomalous magnetic moment of the muon (SM, Álex Miranda Ph. D. Th.)



Álex has focused on the dominant piece of this contribution, evaluated from $\tau \rightarrow$hadrons ν_τ data (instead of $e^+e^- \rightarrow$ hadrons data), which required computing isospin corrections beyond previous literature.

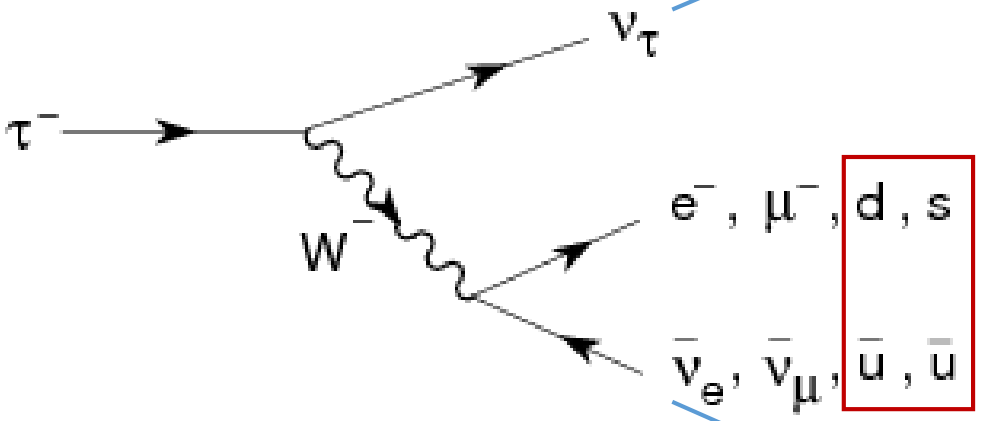
A significant deviation between exp & SM should be New Physics!!

Lepton flavor violating decays including an invisible light boson (Marcela Marín Ph. D. Th.)

Lepton flavor violating decays with two photons

(Fabiola Fortuna & Marcela Marín Ph. D. Th.)

LFV in Little Higgs models (Enrique Ramírez & Iván Pacheco Ph. D. Th.) & bounds on NSI using hadron τ decays (Javier Rendón & Álex Miranda Ph. D. Th.) not discussed today.



LHC EWPO

K & μ decays
$0^+ \rightarrow 0^+$

SMEFT

NEW PHYSICS

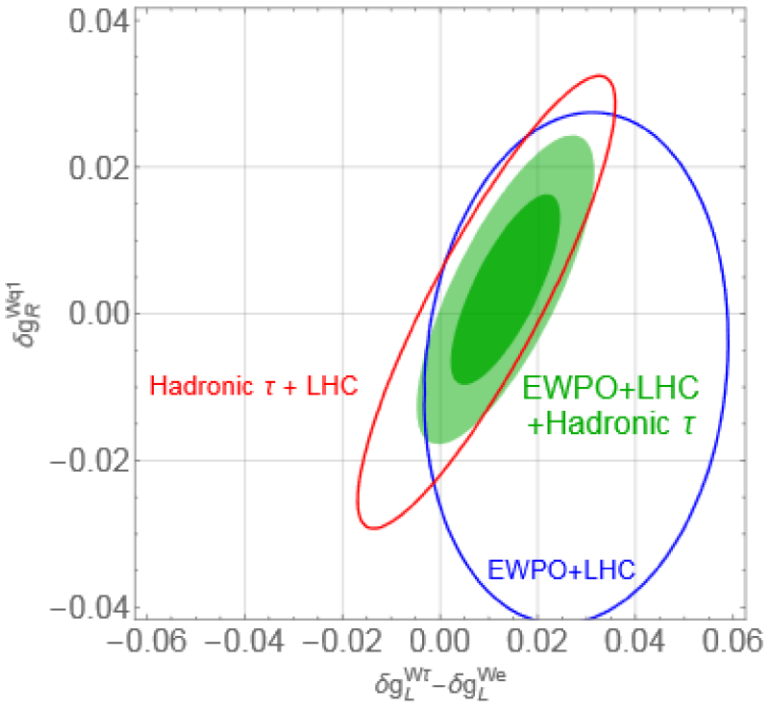
Interesting bounds on LFV process with TeV Majorana neutrinos within LH models **not discussed today.**

LFV in Little Higgs models (Enrique Ramírez & Iván Pacheco Ph. D. Th.) & bounds on NSI using hadron τ decays (Javier Rendón & Álex Miranda Ph. D. Th.) not discussed today.

From ηπ channel: $-0.83\ 10^{-2} \leq \varepsilon_S \leq 0.37\ 10^{-2}$ (Garcés et al. '17)

From ππ channel: $\hat{\epsilon}_T = \left(-1.3^{+1.5}_{-2.2}\right) \cdot 10^{-3}$ (Miranda & Roig '18)

Limits from Cirigliano et al. '18:

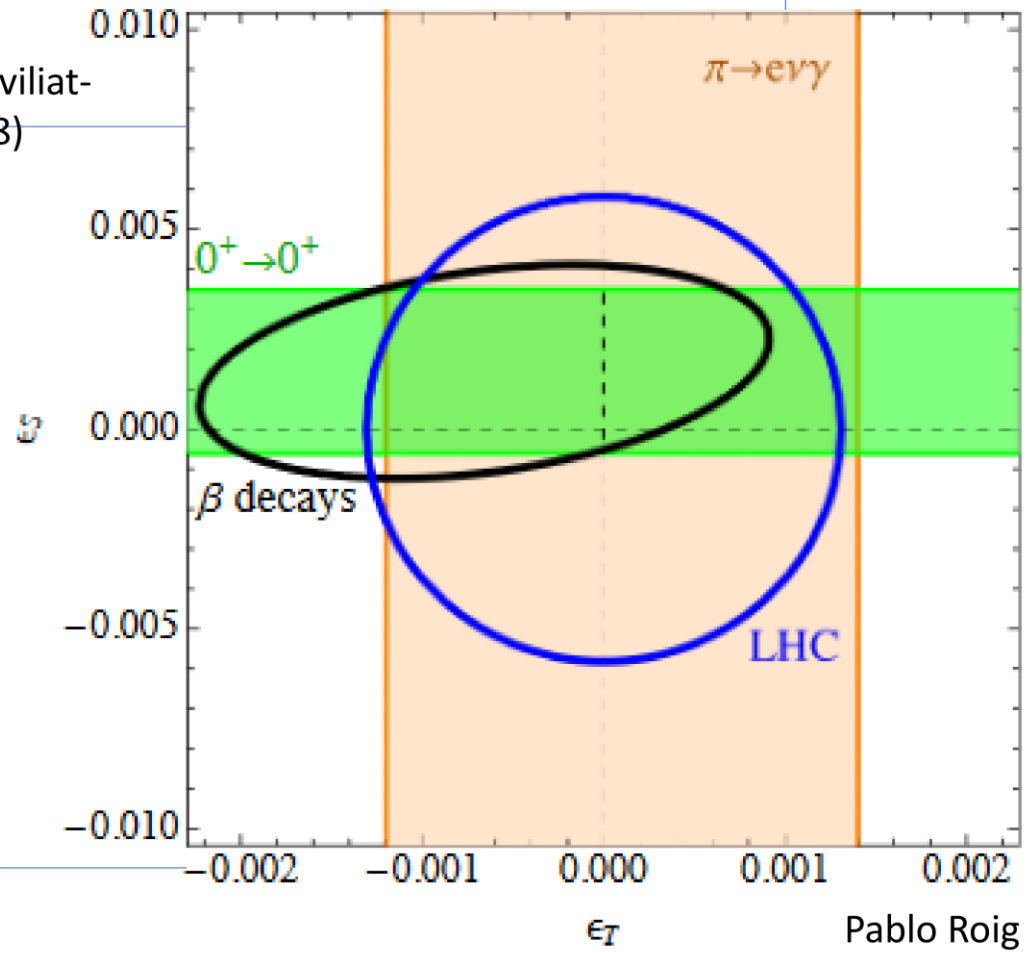


(González-Alonso, Naviliat-Cuncic & Severijns '18)

$\Lambda \approx [5,6]$TeV

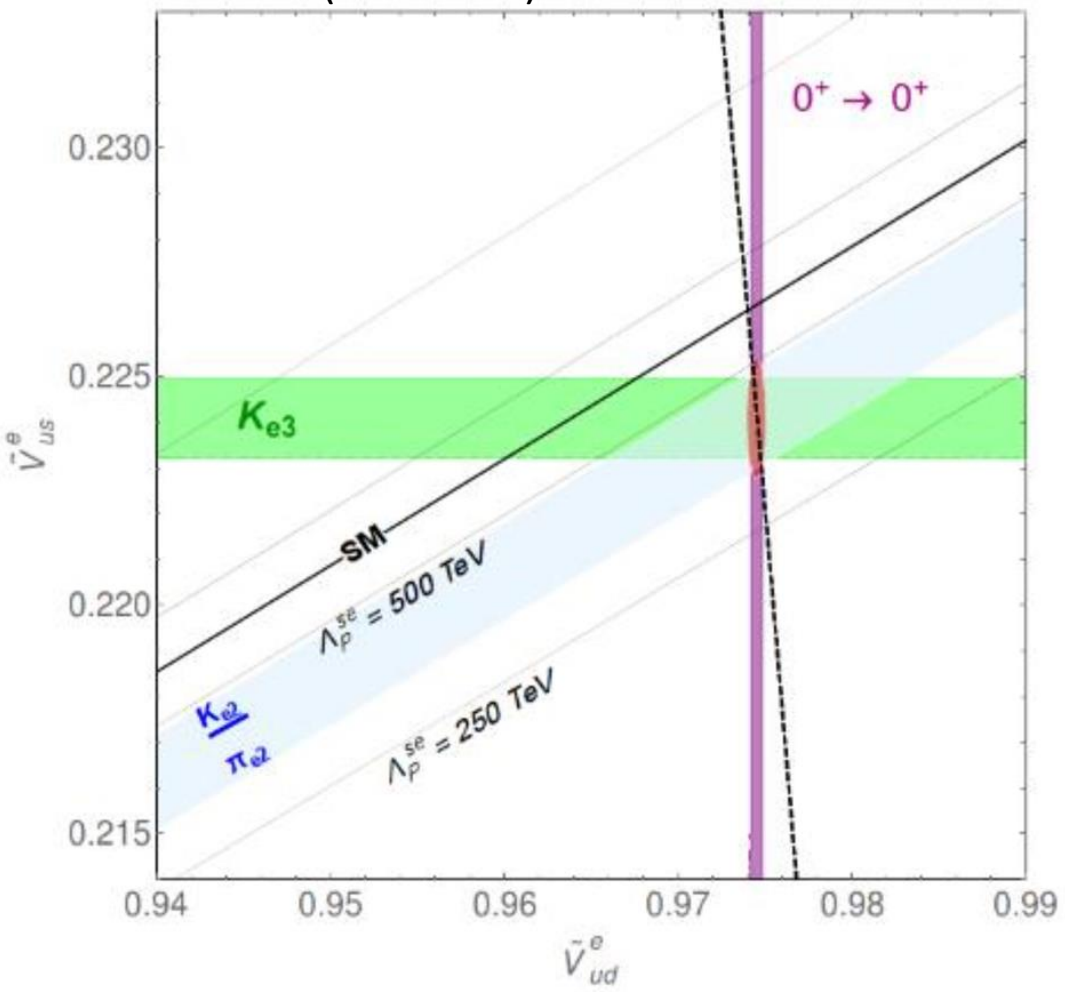
Non-trivial constraints from τ decay!!

$\Lambda \approx v\ (V_{ud}\ \varepsilon_{S,T})^{-1/2}$

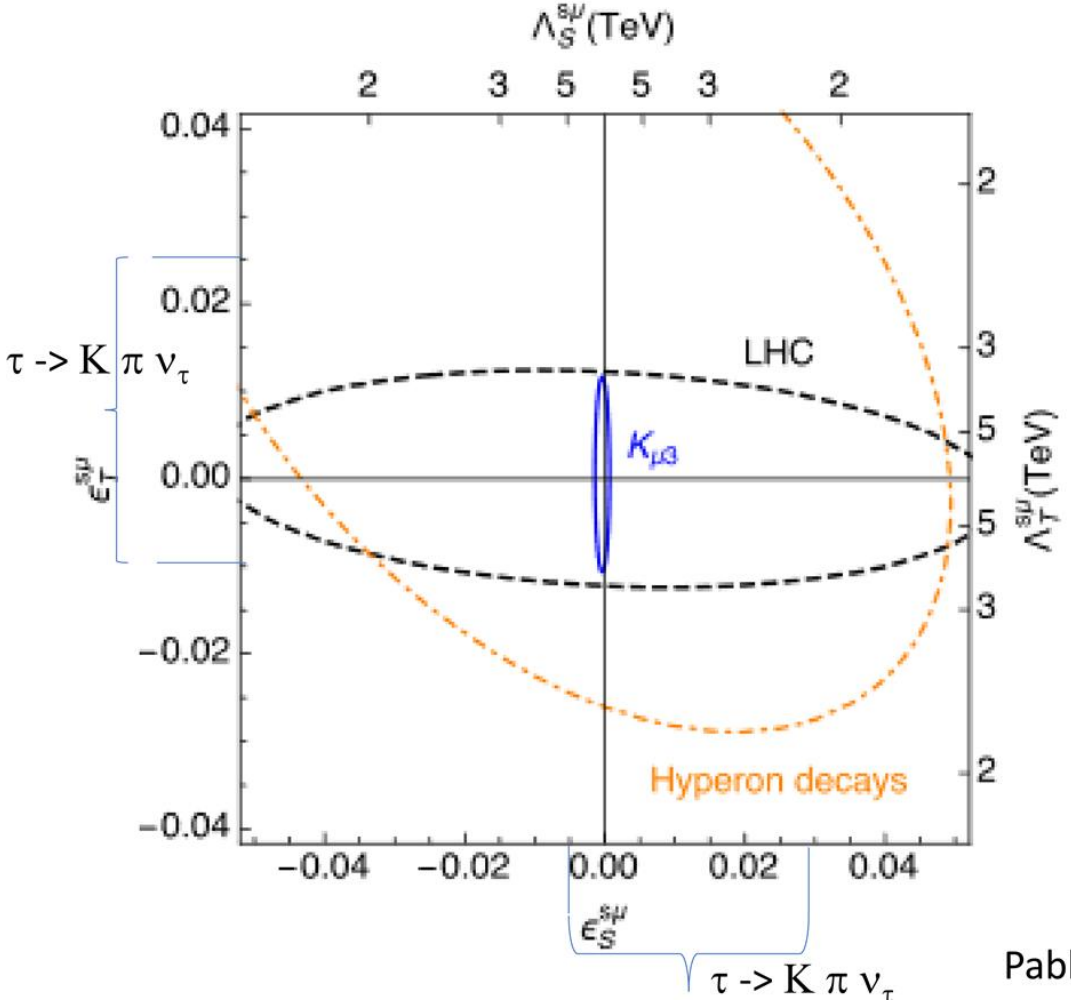


LFV in Little Higgs models (Enrique Ramírez & Iván Pacheco Ph. D. Th.) & bounds on NSI using hadron τ decays (Javier Rendón & Álex Miranda Ph. D. Th.) not discussed today.

Kaon Physics may reach O(500) TeV (González-Alonso et al. '15, '16, '17) (scalar NSI)



$\Lambda \sim v(V_{us}\hat{\epsilon}_{S,T})^{-1/2}$



Pablo Roig

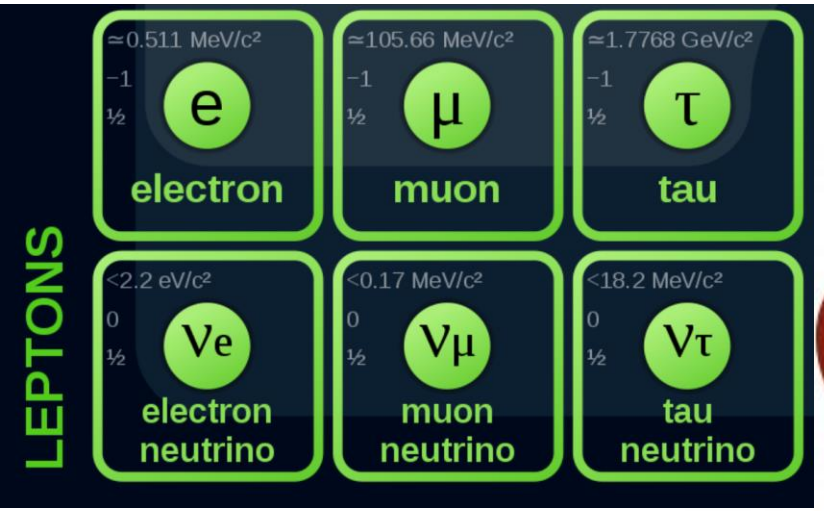
DISCLAIMER

I have not discussed other very interesting NP searches that can be performed through charged leptons physics. Namely:

- **Electron & muon electric dipole moments**
- **$\mu e \rightarrow \mu e$ for $a_\mu^{HVP,LO}$**
- **Dark photons**
- **LU anomalies in semileptonic decays of heavy mesons**
- **Antimatter gravity with muonium**
- **LNV**
- **LFV in nuclei**
- **Baryogenesis through leptogenesis**
- **…**

Belle-II Physics Book

Motivation



Looking for NP, go as leptonic (clean) as possible

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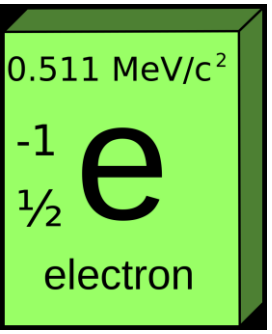

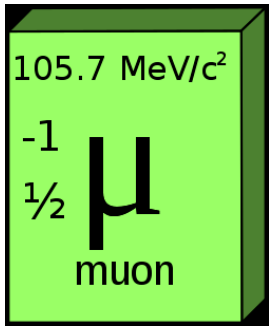

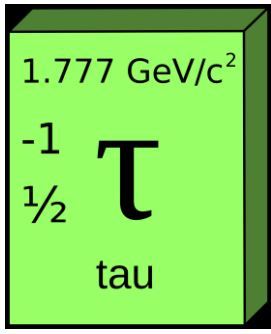

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