Charged Lepton Flavour Violation: An Introduction

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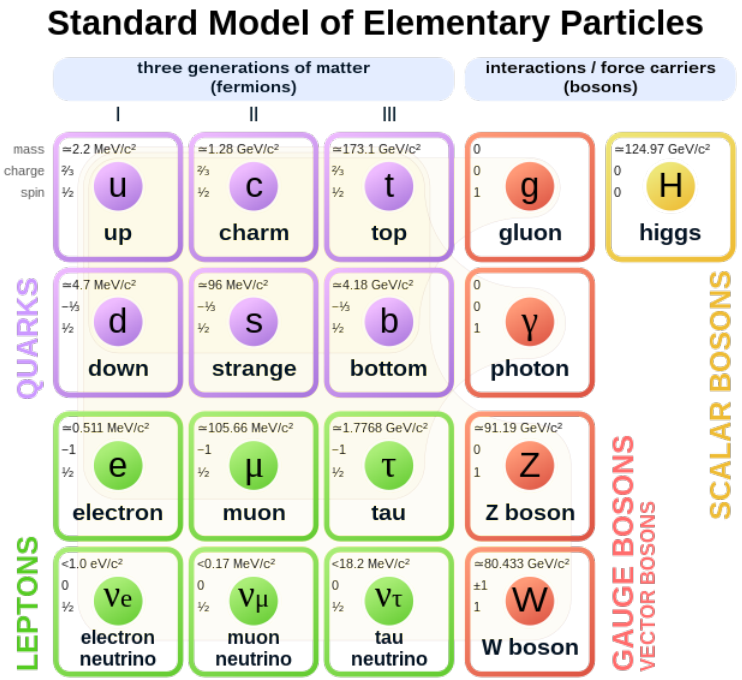
Standard Model conserved quantities

There are a few quantities that are strictly conserved in SM processes:

- Electric & colour charge
- Baryon number B
- Lepton number L

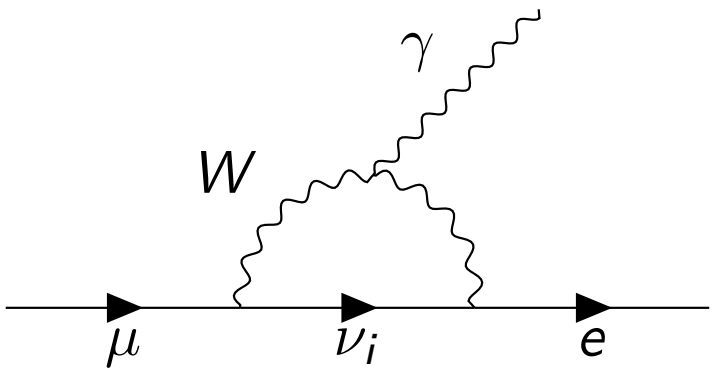
If neutrinos were massless, individual lepton flavour numbers L_e, L_μ, and L_τ would be conserved[1]. With massive neutrinos, only L is conserved.
(Provided neutrinos are Dirac fermions and not Majorana fermions)



[1] M.E. Peskin, 2018, p.286

Charged Lepton Flavour Violation (CLFV)

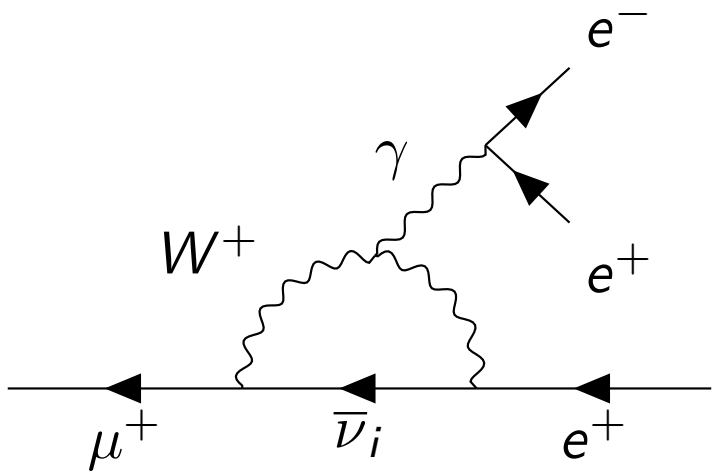
- We already see lepton flavour being violated in neutrino oscillation
- Best estimates of $\mu \to e\gamma$ rates by the same mechanism are $< 10^{-54}$, which are not realistically measurable[2]. Similar for other processes
- Thus observing these processes implies new physics is at play!
- Example processes would be $\mu \to e\,e\,e$, $\mu \to e\gamma$, and $\tau \to \mu, e + X$

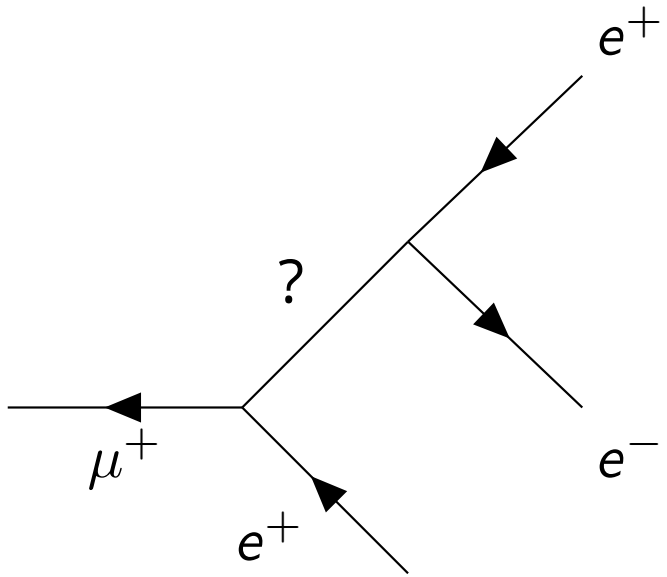


[2] de Gouvea, A., & Vogel, P. (2013). Lepton Flavor and Number Conservation, and Physics Beyond the Standard Model.

$\mu \to e\,e\,e$

- We could see this as $\mu^+ \to e^+e^+e^-\nu_\mu\overline{\nu}_e$ and not be new physics
- Thus we look for this with no energy loss
- Could be $\mu \to e\gamma$ with more steps, or could be something else entirely
- the SINDRUM experiment puts a rate limit of 10^{-12} with future experiments aiming for 10^{-163}





[3] Ardu, M., & Pezzullo, G. (2022). Introduction to Charged Lepton Flavour Violation

$\mu^- N \to e^- N$

- Conversion of a muon captured by a nucleus into an electron
- Bombarding a nucleus with muons to see an outgoing electron
- Should result in a monoenergetic electron, $\approx 104.96\,\mathrm{MeV}$ for most nuclei
- Important to ignore $\mu^- \to e^- \overline{\nu}_e \nu_\mu$
- Rates for gold and titanium are about $< 7 \times 10^{-13}$

MEG detector?

Best theories for explaining it

Conclusion