

Theory

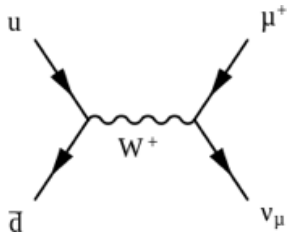
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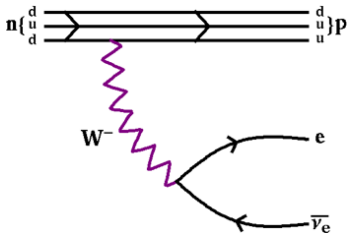
Focus topic: LLPs

Long-lived particles (LLPs) in the Standard Model (SM)

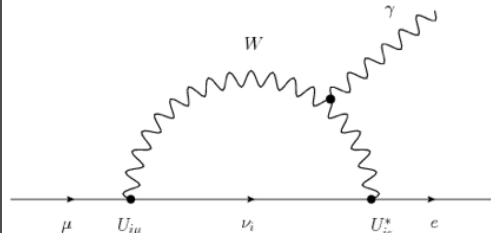
$$\pi^+ \rightarrow \mu^+ \nu_\mu$$



$$n \rightarrow p e \bar{\nu}_e$$



$$\mu \rightarrow e \gamma$$



Charged pion

- Decay via weak interactions
- Decay extremely off-shell

$$\Gamma_{\pi^+} \propto g_W^2 \left(\frac{m_\pi}{m_W} \right)^4 m_\pi$$

Neutron

- Proton and neutron are almost mass degenerate due to isospin
- Decay extremely off-shell

$$\Gamma_n \propto g_W^2 \left(\frac{\Delta_{np}}{m_W} \right)^4 \Delta_{np}, \quad \Delta_{np} = m_n - m_p$$

Muon

- Flavour changing neutral current
 - Lepton flavour only violated by neutrino masses and Yukawa couplings
- $$\text{BR}(\mu \rightarrow e \gamma) \propto 10^{-13}$$

Generically

- Off-shell decay
- Small mass splitting
- Small coupling due to hierarchy or loop suppression

$$\Gamma \propto \lambda^2 \left(\frac{m}{M} \right)^n m$$

LLPs beyond the SM

New Physics

Any model with such features can contain LLPs

- Supersymmetry
- Dark Matter models
- Extended Higgs sectors

Portals to hidden sectors

- Many extension to the SM feature hidden sectors
- Often motivated by DM candidates

Prime examples

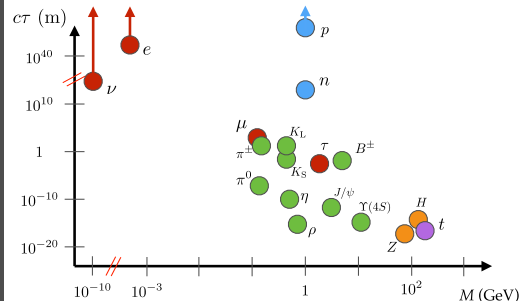
- Axion like particles
- Heavy neutral leptons (HNLs)
- Hidden U(1) / New gauge bosons

Future work

- Improving prediction for discovery reaches
- Sensitivity prediction to measure properties

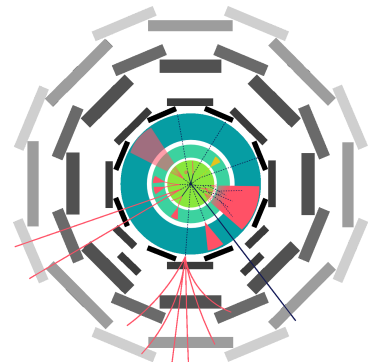
LLPs in the SM

[1903.04497]



LLP signatures

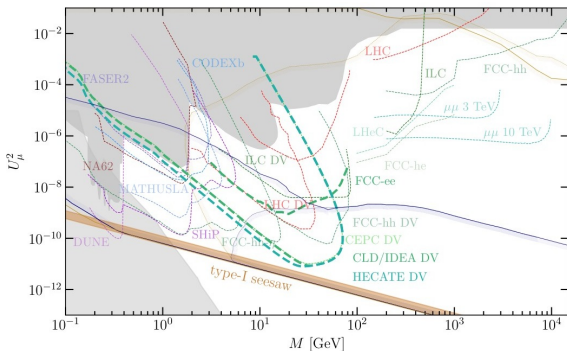
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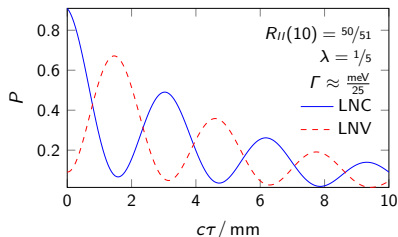
Example: HNLs and lepton number violation (LNV)

Discovery reaches

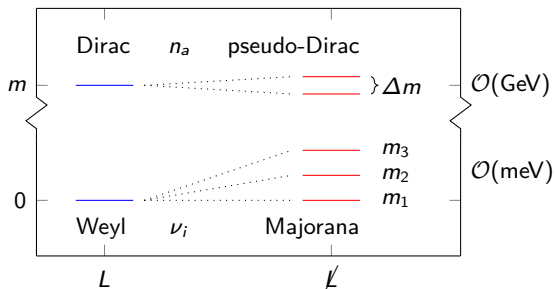
[2203.05502]



Mass splitting Δm generates oscillations



Neutrino masses require pseudo-Dirac HNLs



Measuring LNV at the FCC-ee (preliminary)

