$$\Gamma_f = 2\pi \underbrace{|T_f|^2}_{\propto \alpha} \underbrace{\rho(E_f)}_{\sim \text{mass}}$$

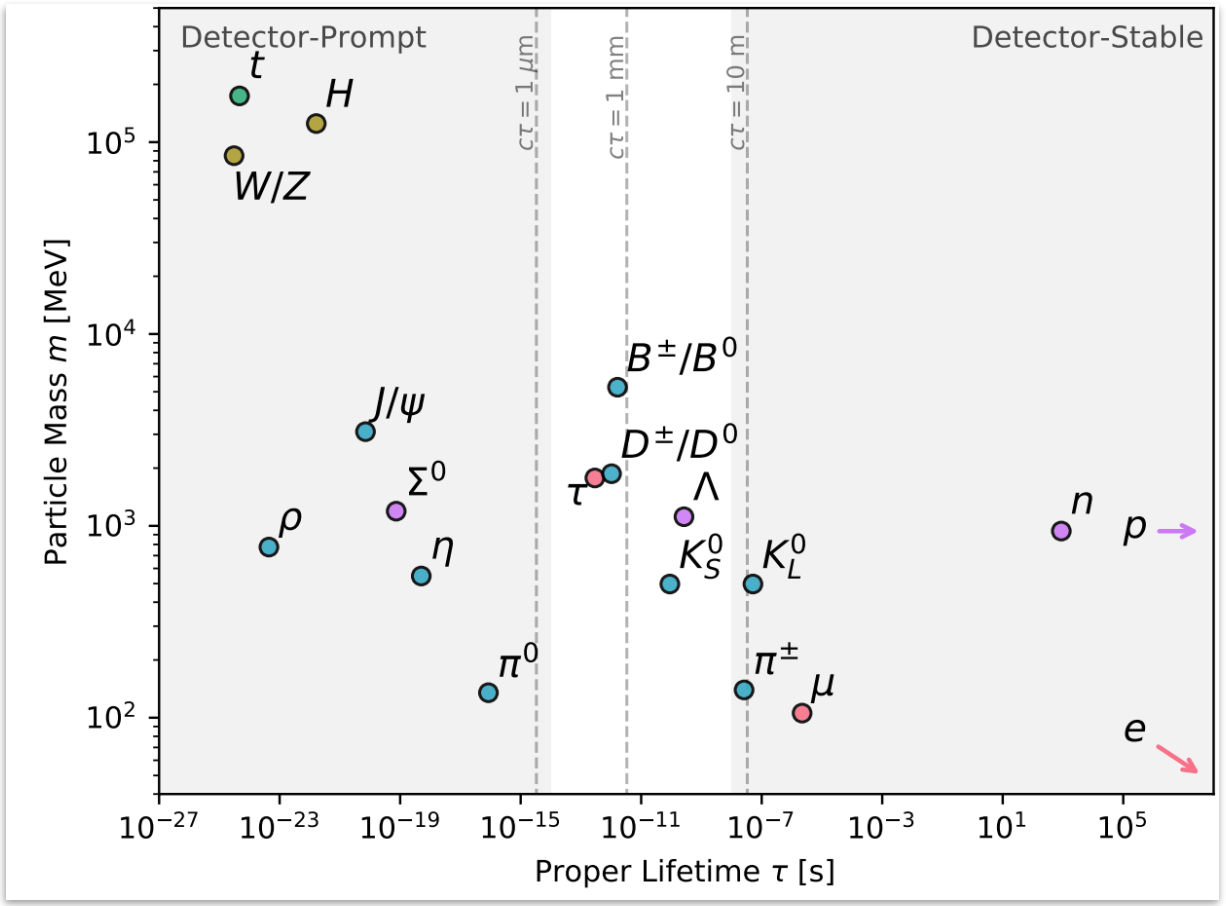
$$\tau = \left(\sum \Gamma_f\right)^{-1}$$

Coupling constant

Density of states

Scale suppression

- Particle decay rate : strong force > electromagnetic or weak
- Symmetries : Small DOS → a longer lifetime
- General trend : High mass particles → smaller lifetimes
- Decay : suppressed by scale of the physical system mediating decay



small coupling

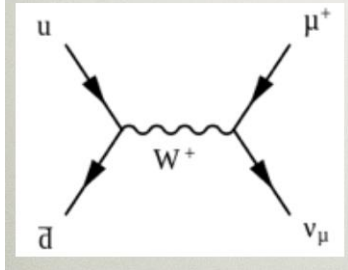
$$\Gamma \sim y^2 \left(\frac{m}{M}\right)^n m$$

Set by symmetry structure, typically n ≥ 4

$m \ll M$ hierarchy of scales

Example 1 : Charged pion (Small coupling constant)

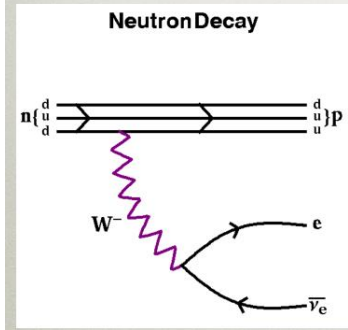
$\pi^+ \to \mu^+ \nu_\mu$



- Quark flavour conserved by all but weak interactions
- Decay highly off-shell:

$$\Gamma_{\pi^+} \sim g_W^2 \left(\frac{M_\pi}{M_W}\right)^4 M_\pi$$

Example 2 : Neutron (Phase space suppression)



- Isospin ensures that proton and neutron are nearly degenerate
- Decay highly off-shell:

$$\Gamma_{\pi^+} \sim g_W^2 \left(\frac{M_n - M_p}{M_W}\right)^4 (M_n - M_p)$$