D   Homework: Electroweak I (due Thu 24th Apr 5pm)

D.1   Parity violation

Write a few sentences and draw a diagram describing the cobalt-60 experiment. Discuss the key experimental observations and arguments for how it demonstrates the violation of parity symmetry by the weak force.

D.2   Kaon weak interactions

(i) Draw the Feynman diagrams showing the quark lines and label the quark flavours for these kaon decays: $K_{\text{long}}^0 \to \pi^+\pi^-$ and $K_{\text{long}}^0 \to \pi^+\pi^-\pi^0$. What are the charge-parity quantum numbers of the two-pion and three-pion final states? Why does observing $K_{\text{long}}^0 \to 2\pi$ show that charge-parity symmetry is not conserved by the weak force?

(ii) Consider kaon mixing $K^0 \leftrightarrow \bar{K}^0$ diagram in eq. (82). Draw the other topologically distinct one-loop Feynman diagram where the $W^\pm$ bosons are vertical. For the internal quarks being the up quark, write down the CKM matrix elements and estimate the Cabibbo suppression in the amplitude. Draw the Feynman diagram for $K^0 \to \mu^+\mu^-$.

D.3   Collider detectors

For each of the following e^-e^+ processes, draw your own version of the detector diagram below labelled by tracker, electromagnetic (ECal) and hadronic calorimeter (HCal), muon system (MS), then sketch how each of these final states appear in the detector subsystems:

(a) $e^-e^+ \to \mu^-\mu^+\gamma$,

(b) $e^-e^+ \to u\bar{u}$,

(c) $e^-e^+ \to qqg$,

(d) $e^-e^+ \to e^-e^+\mu^-\mu^+$,

(e) $e^-e^+ \to b\bar{b}$,

(f) $e^-e^+ \to \tau^-\tau^+$ with $\tau^\pm \to \pi^\pm\pi^0\nu_\tau$,

(g) $e^-e^+ \to W^-W^+$ with $W^- \to e^-\nu_e, W^+ \to u\bar{d}$,

(h) $e^-e^+ \to t\bar{t}$ with $t \to be^+\nu$ and $\bar{t} \to \bar{b}u\bar{d}$.
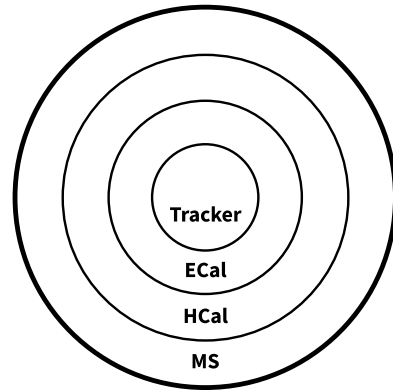
Discuss how the signatures would differ at a proton–proton collider. Given the rest lifetime of a tau-lepton is 2.9×10^{-13} s and B^+ meson is 1.6×10^{-12} s, estimate the mean distance these particles travel if they have momentum $p = 10, 100, 1000$ GeV.