QFT2 — Assignment 2: Interacting Nucleons

1. **nucleon-sigma model**

Consider the interaction Lagrangian density $\mathcal{L}_{int} = g(\bar{n}\sigma p + \bar{p}\sigma^* n)$ where $n \equiv \psi_n$ describes a neutron of mass 1.0 GeV; $p \equiv \psi_p$ describes a proton of mass 0.6 GeV, and $\sigma \equiv \phi_\sigma$ describes a charged spin zero boson of mass 0.2 GeV.

(i) Write the full Lagrangian density for this theory (you do not have to derive it).

(ii) Find the equations of motion for σ and n.

(iii) Write the propagators and vertices for this theory (you do not have to derive them).

(iv) If $\mathcal{L}_{int}$ were $g(\bar{n}\gamma_5\sigma p - \bar{p}\gamma_5\sigma^* n)$ what would the vertices be? Carefully label Dirac indices.

2. **nucleon decay**

(v) Evaluate the invariant amplitude for the decay $n \to \sigma p$ using your Feynman rules.

(vi) Compute the total (unpolarised) decay width. Use your trace theorems!

(vii) Evaluate the half life of a neutron in seconds taking $g = 0.5$.

3. $\bar{n}p$ **scattering**

(viii) Compute the unpolarised cross section for $\bar{n}p \to \bar{n}p$ scattering. Write your answer in terms of Mandelstam-s.

4. np **scattering**

(ix) Compute the CMF unpolarised differential cross section for $np \to np$ scattering.

5. $n\sigma$ **scattering**

(x) Compute the CMF unpolarised differential cross section for $n\sigma \to n\sigma$ scattering. What happens when you attempt to compute the angular integral?