Quantum Field Theory Exercises week 7

Exercise 11: decay rates, cross sections and reaction channels

Read § 2.8.3 of the lecture notes about CM kinematics and consider the scalar Yukawa theory.

(a) Calculate the lowest-order decay width $\Gamma_{\phi\to\psi\bar{\psi}}$ in the rest frame of the decaying particle. For which masses is this decay possible?

(b) Consider the process $\psi\bar{\psi} \to \phi\phi$ in the centre-of-mass frame.

- Which channels contribute to this process?
- What do the corresponding diagrams say about the θ-dependence?
- For which centre-of-mass energies can this process occur?
- Calculate the lowest-order differential cross section $\big(\mathrm{d}\sigma/\mathrm{d}\Omega\big)_{\mathrm{CM}}$.

(c) Consider the process $\psi\bar{\psi} \to \psi\bar{\psi}$ in the centre-of-mass frame.

- Which channels contribute to this process?
- What are the ranges of the Mandelstam variables?
- For which centre-of-mass energies can this process occur?
- Calculate the lowest-order differential cross section.
- Assume that $m > 2M$. Look at the energy dependence of both reaction channels separately. Do you notice something special in one of them?
- Use the other reaction channel to determine whether the Yukawa interaction between ψ-particles and $\bar{\psi}$-particles is attractive or repulsive.

  Hint: don't perform an explicit calculation, just use the analogy with the calculation that is presented on pages 54 and 55 of the lecture notes.