Physikalisches Institut
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Theoretische Physik

Exercise 4
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Crash Course in Theoretical Particle Physics

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–Class Exercises–

4.1 Drawings of quantum interactions

In the following exercise, draw all Feynman diagrams with no internal loops that correspond to the given process with the given interaction Lagrangian.

(a) $-\mathcal{L}_{\text{int}} = \frac{\lambda}{4!}\phi^4, \quad \phi(p_1) + \phi(p_2) \to \phi(k_1) + \phi(k_2)$

(b) $-\mathcal{L}_{\text{int}} = \frac{\kappa}{3!}\phi^3, \quad \phi(p_1) + \phi(p_2) \to \phi(k_1) + \phi(k_2)$

(c) $-\mathcal{L}_{\text{int}} = \frac{\kappa}{2}\Phi\phi^2, \quad \Phi(p) \to \phi(k) + \phi(q)$

(d) $-\mathcal{L}_{\text{int}} = \frac{\lambda}{4}\Phi^2\phi^2, \quad \Phi(p) \to \phi(k) + \phi(q)$

(e) $-\mathcal{L}_{\text{int}} = \frac{\kappa}{2}\phi^2\Phi + \frac{\lambda}{4}\Phi^2\phi^2, \quad \phi(p_1) + \phi(p_2) \to \Phi(k_1) + \Phi(k_2)$

4.2 Feynman graph for the matrix element in ABC theory

Consider a theory containing three *different* real scalar fields A, B, C, described by ϕ_A, ϕ_B and ϕ_C and the Lagrangian

$$\mathcal{L} = \sum_{i=A,B,C} \frac{1}{2}\left(\partial^\mu\phi_i\partial_\mu\phi_i - m_i^2\phi_i^2\right) - A\phi_A\phi_B\phi_C\,. \tag{1}$$

(a) Determine the lowest-order amplitude for $\phi_A(p) + \phi_B(k) \to \phi_A(p') + \phi_B(k')$. [*Hint:* There are two diagrams.]

(b) Specify p, k, p', k' in the center of mass frame given that A and B have both mass m, ϕ_A has energy E and is scattered by an angle θ.

(c) Find $d\sigma/d\Omega$ for this process in the CM frame, assuming $m_A = m_B = m, m_C = 0$. Express your answer in terms of the incident energy, E, and the scattering angle θ.

(d) Find $d\sigma/d\Omega$ for this process in the lab frame, assuming B is much heavier than A, and remains stationary. A is incident with energy E. [*Hint:* Use results from the previous exercise sheet!]

(e) For the CM frame result, find the total cross section, σ.