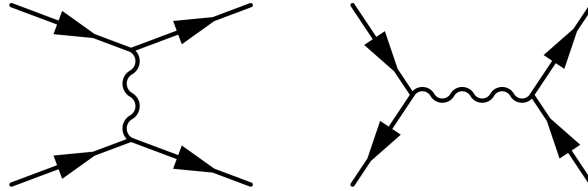


PARTICLE PHYSICS 1 : EXERCISE 2

1) Scattering and annihilation Feynman diagrams

Particle interactions fall into two main categories, scattering processes and annihilation processes, as indicated by the Feynman diagrams below. Draw the lowest-order Feynman diagrams



for the scattering and/or annihilation processes

- (a) $e^-e^- \rightarrow e^-e^-$
- (b) $e^+e^- \rightarrow \mu^+\mu^-$
- (c) $e^+e^- \rightarrow e^+e^-$
- (d) $e^-\nu_e \rightarrow e^-\nu_e$
- (e) $e^-\bar{\nu}_e \rightarrow e^-\bar{\nu}_e$

In some cases there may be more than one lowest order Feynman diagram.

2) Centre-of-mass energy

The maximum of the π^-p cross section corresponds to the resonant production of the Δ_0 baryon (i.e. $\sqrt{s} = m_{\Delta}$). This maximum occurs at a pion momentum $p_{\pi} = 300$ MeV with the protons at rest. What is the mass of the Δ_0 ?

3) Rutherford cross section

In the lecture you computed the full Rutherford scattering cross section. Compute the relative fraction of α -particles scattering at the angle $\theta > \theta_0 = \pi/2$ for an experiment using platinum foil with a thickness of $\delta = 8 \cdot 10^{-5}$ cm. The average energy of the α -particles is 6 MeV, the platinum density is $\rho = 21.5$ g/cm³, the charge is $Z=78$ and the mass is $A=195$ (Reminder : the Avogadro number is $N_A = 6 \cdot 10^{23}$ mole⁻¹). Assume that the α -particles interact only once.

4) Particle lifetimes and experiments

LHCb is a centre-of-mass experiment located in one of the four collision points at the Large Hadron Collider (LHC). Its experimental decay volume starts at the collision point and is ~ 1 m long. NA62 is instead a fixed-target experiment whose decay volume starts 100 m away from the target position (where particles are produced) and has a length of ~ 70 m.

Consider the particles listed in Table 1. Their typical momenta in LHCb/NA62 as well as their masses and lifetimes are reported.

- (a) Based on the definition given in the lecture, classify the particles in stable, long-lived and short-lived for the two experiments.
- (b) Which particles can we study with the two different experiments?
- (c) What is the fraction of particles that decay in the sensitive decay volume?

Particle type	K_s	K^+	π^+	B^0	D^0	B^+	D^+
p [GeV]	20	75	75	40	40	80	50
m [GeV]	0.5	0.5	0.139	5.3	1.9	5.3	1.9
$c\tau$ [m]	0.025	3.7	7.8	$4.6 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$	$4.9 \cdot 10^{-4}$	$3.1 \cdot 10^{-4}$

TABLE 1