

1: The decay rate of the K^* meson is $\Gamma = 51 \text{ MeV}$. (a) What is its mean lifetime τ in MeV^{-1} (i.e., in ‘particle physics’ units)? (b) What is τ in seconds (i.e., in normal units)?

2: High energy particle reactions often produce large numbers of particles in the final state, including many photons. These usually come from neutral pions, which almost always decays very quickly into two photons, i.e. $\pi^0 \rightarrow \gamma\gamma$. Suppose in a particular event, three photons are detected with the following energies and momentum components measured in GeV:

photon	E	p_x	p_y	p_z
(1)	1.49	0.91	-0.47	1.08
(2)	1.43	-0.79	0.64	-1.00
(3)	0.46	0.31	-0.08	0.33

(a) Compute the mass of the first photon and confirm that to within the accuracy given, it is zero. (Recall $m^2 = E^2 - p^2$.)

(b) By computing the invariant mass of each possible pair and comparing this to the neutral pion’s mass of 0.135 GeV, find out if any of the photons can be identified as the decay products of a π^0 . (Use equation (2.13) from the lecture notes and recall $\vec{p}_i \cdot \vec{p}_j = p_i p_j \cos \theta_{ij} = E_i E_j \cos \theta_{ij}$ since for photons $E = p$; use this to compute $\cos \theta_{ij}$ for each pair. Because of round-off errors, one should not expect exact agreement.)

3: Draw possible Feynman diagrams for the following decays or scattering reactions. Remember to build the diagrams using only the vertices we saw in the lectures and ensure that all quantum numbers (e.g. B, L, Q) are conserved at every vertex. Label all particles and state what coupling (e, g or g_s) is associated with each vertex. You do not need to give the Ze coupling for (c); it is enough to know that this is a specific function of e and g .

(a) $\tau^- \rightarrow \nu_\tau \bar{u} d$

(b) $\gamma\gamma \rightarrow \tau^+ \tau^-$

(c) $e^+ e^- \rightarrow \gamma Z$

(d) $e^+ e^- \rightarrow q \bar{q} g$ (where q stands for any flavour of quark, g is a gluon).

(e) $n \nu_e \rightarrow p e^-$ (draw the n and p as the appropriate combination of quarks)

(f) $e^+ e^- \rightarrow \mu^+ \mu^- \gamma$