Two–Particle Collisions

This chapter deals with collisions between two particles characterized by an energetic projectile striking a stationary target. Three categories of projectiles of interest in medical physics are considered: \textit{light charged particles} such as electrons and positrons, \textit{heavy charged particles} such as protons and \(\alpha\) particles, and \textit{neutral particles} such as neutrons. The targets are either atoms as a whole, atomic nuclei, or atomic orbital electrons. The collisions are classified into three categories: (1) Nuclear reactions, (2) Elastic collisions, and (3) Inelastic collisions.
The many types of interacting particles as well as the various possible categories of interactions result in a wide range of two-particle collisions of interest in nuclear physics and in medical physics. Several parameters, such as the $Q$ value and energy threshold in nuclear reactions, as well as energy transfer in elastic scattering, used in characterization of two-particle collisions are defined in this chapter and determined using considerations of momentum and energy conservation classically as well as relativistically. Many of these parameters play an important role in radiation dosimetry through their effects on stopping powers, as discussed in Chap. 6. They also play an important role in the production of radioactive nuclides, as discussed in Chap. 12.

5.1 Collisions of Two Particles: General Aspects

A common problem in nuclear physics and radiation dosimetry is the collision of two particles in which a projectile with mass $m_1$, velocity $v_1$ and kinetic energy ($E_{K1}$) strikes a stationary target with mass $m_2$ and velocity $v_2 = 0$. The probability or cross section for a particular collision as well as the collision outcome depend on the physical properties of the projectile (mass, charge, velocity, kinetic energy) and the stationary target (mass, charge).

As shown schematically in Fig. 5.1, the collision between the projectile and the target in the most general case results in an intermediate compound that subsequently decays into two reaction products: one of mass $m_3$ ejected with velocity $v_3$ at an angle $\theta$ to the incident projectile direction, and the other of mass $m_4$ ejected with velocity $v_4$ at an angle $\phi$ to the incident projectile direction.

Targets are either atoms as a whole, atomic nuclei, or atomic orbital electrons. In an interaction with a projectile, targets are assumed to be stationary and they interact with the projectile either through a Coulomb interaction when both the projectile and the target are charged or through a direct collision when the projectile is not charged.

Projectiles of interest in medical physics fall into one of three categories, each category characterized by its own specific mechanism for the interaction between the projectile and the target. The three categories of projectile are: (1) heavy charged particle, (2) light charged particle, and (3) neutron:

1. **Heavy charged particles**, such as protons, $\alpha$ particles, and heavy ions, interact with the target through Coulomb interactions. Typical targets for heavy charged particles are either atomic nuclei or atomic orbital electrons.
2. **Light charged particles**, such as electrons and positrons, interact with the target through Coulomb interactions. Typical targets for light charged particles are either atomic nuclei or atomic orbital electrons.
3. **Neutrons** interact with the target through direct collisions with the target. Typical targets for neutrons are atomic nuclei.