14.1: Prelude to Relativistic Collisions

In supercolliders such as the ones at CERN in Geneva and (formerly) Fermilab in Chicago, small particles like electrons and protons are accelerated to speeds near that of light, then made to collide with each other in an attempt to create exotic types of matter (i.e., non-common particles). The very reason why this can be done is the relation between energy, mass, and momentum given by the general version of Einstein's famous equation.

$$E=mc^2 \tag{14.1.1}$$

Einstein's equation tells us that if the incoming particles have sufficiently high kinetic energy, we can create new particles with more mass than the originals had. The process by which this happens is the realm **quantum field theory**, but the mechanics of the collisions can be studied within special relativity.

Just like in classical mechanics, we can define a *totally inelastic collision* as any collision in which the particles stick together. We define a *totally elastic collision* as a collision in which the momentum, kinetic energy, *and* mass of all particles are conserved. We'll have one more type, that has no classical counterpart: *radioactive decay*, in which a particle falls apart into multiple particles - a sort of time-reversed inelastic collision. All cases can be analyzed using the conservation of energy-momentum. Although that basic concept is in principle sufficient, there are many cases for which writing out the components of the energy-momentum four-vector as four equations are not the easiest way to find (say) the energies or momenta of the outgoing particles. There are some other tricks that you can use - in particular, the invariance of the length of the energy-momentum four-vector, both in a collision process and under a Lorentz transformation. A few examples will help to illustrate this point.