2.2: Targets

There are two ways to make the necessary collisions with the accelerated beam: Fixed target and colliding beams.

In fixed target mode the accelerated beam hits a target which is fixed in the laboratory. Relativistic kinematics tells us that if a particle in the beam collides with a particle in the target, their center-of-mass (four) momentum is conserved. The only energy remaining for the *reaction* is the relative energy (or energy within the center of mass frame). This can be expressed as

$$E_{CM} = \left[m_b^2c^4 + m_t^2c^4 + 2m_tc^2E_L\right]^{1/2}$$

where m_b is the mass of a beam particle, m_t is the mass of a target particle and E_L is the beam energy as measured in the laboratory. as we increase E_L we can ignore the first tow terms in the square root and we find that

$$E_{CM} \approx \sqrt{2m_tc^2E_L},$$

and thus the center-of-mass energy only increases as the square root of the lab energy!

In the case of colliding beams we use the fact that we have (say) an electron beam moving one way, and a positron beam going in the opposite direction. Since the center of mass is at rest, we have the full energy of both beams available,

$$E_{CM} = 2E_L.$$

This grows linearly with lab energy, so that a factor two increase in the beam energy also gives a factor two increase in the available energy to produce new particles! We would only have gained a factor $\sqrt{2}$ for the case of a fixed target. This is the reason that almost all modern facilities are colliding beams.