

# Particle Interactions

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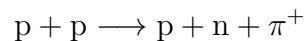
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An interaction describes a collision between two particles resulting in new particles being formed, or a decay of an unstable particle into other particles.

## Collisions

When particles collide, the total energy that they contain is their  $\text{rest energy}$  and the energy that they have due to their  $\text{motion}$ . After the collision, the particles produced may have different  $\text{rest energies}$  and  $\text{kinetic energies}$ , but the total must remain the same ( $\text{conservation of energy}$ ). This means that we can produce different particles by collisions.

e.g.

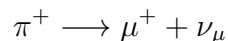


The collision of two protons gives  $\text{a neutron}$  and  $\text{a pi-plus}$ . Some of the kinetic energy of the protons goes into producing the extra mass of the  $\text{neutron}$  and pion.

## Decays

Most particles are  $\text{unstable}$ , which means that they decay into other particles (similar to radioactive decay). A particle will decay into other particles as long as the total mass of the products is less than the  $\text{mass of the parent particle}$ , so that any excess mass will go into the  $\text{kinetic energy}$  of the products.

e.g.



mass of  $\pi^+ = 2.5 \times 10^{-28} \text{ kg}$

mass of  $\mu^+ = 1.9 \times 10^{-28} \text{ kg}$

mass of  $\nu_\mu$  is almost zero ( $< 3.4 \times 10^{-34} \text{ kg}$ )

All unstable particles have a characteristic  $\text{lifetime}$ , which is the average time that it will take for that particle to decay.

## Conservation laws

In every interaction:

1.                      must be conserved
2.                      must be conserved
3.                      must be conserved
4.                      must be conserved
5.                      must be conserved
6. strangeness  $S$ 
  - (a) is conserved in collisions
  - (b) changes by        in a weak decay

## Notes

- Strange particles decay by strong or weak decays, and these can usually be distinguished by the lifetime of the decay (the typical lifetimes for strong decays are typically  $10^{-23}$  s, and weak decays typically  $10^{-8}$  s). Strangeness may be ‘lost’ in a weak decay: no strange particles are stable, and when one decays, the strangeness can change by  $\pm 1$ , so that the total strangeness gets closer to zero. Although strangeness can change in this way in weak decays, in strong decays of strange particles, strangeness **is** conserved. We shall presume all strange decays to be weak, i.e. strangeness will change if a strange particle decays, as a strange quark changes into a non-strange quark.
- Energy/mass considerations will not be taken into account, as in principle any energy can be converted into mass in accelerators.

The general method of solution is to write  $Q$ ,  $B$ ,  $L$ ,  $S$  below the interaction and check for conservation.