

Energy and momentum units in particle physics

Use of 'GeV-type' units rather than SI in Particle Physics

In ordinary Newtonian physics, given the **kinetic energy** E_k of a particle (4 Joules, say) and its **momentum** p (4 kg m/s), one can calculate

$$m = p^2/2E_k = 2 \text{ kg}$$

In highly relativistic collisions at the LHC, the **total energy** E of a particle is measured by detectors quaintly called 'calorimeters', and the **momentum** p by determining the curvature of charged tracks moving in a magnetic field.

Then, using $E^2 = p^2c^2 + m^2c^4$, we can calculate the mass m :

$$m = \sqrt{\frac{E^2 - p^2 c^2}{c^4}}$$

Given E in Joules, p in kg m/s, and $c = 3 \times 10^8$ m/s, this yields m in kg.

However:

Particle physicists measure energies in GeV, where $1 \text{ GeV} = 10^9 \text{ eV}$ = energy gained by an electron or proton accelerated through 10^9 volts.

How does one use $E^2 = p^2c^2 + m^2c^4$ to measure mass using particle physicists' units?

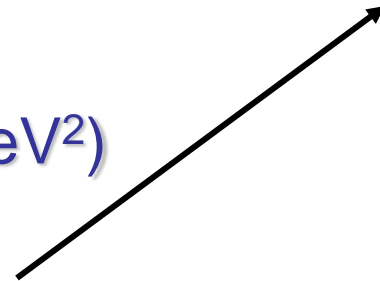
For the units in each term of $E^2 = p^2c^2 + m^2c^4$ to be the same, p must be in GeV/c and m must be in GeV/c².

Then E^2 (in GeV²) = p^2 (in GeV²/c²) c^2 + m^2 (in GeV²/c⁴) c^4

Physicists 'simplify' this by writing it as

$$E^2 \text{ (in GeV}^2\text{)} = p^2 \text{ (in GeV}^2\text{)} + m^2 \text{ (in GeV}^2\text{)}$$

So when you see $E^2 = p^2 + m^2$ think of



What is a highly relativistic particle?

$$E^2 = p^2c^2 + m^2c^4$$

$$p^2c^2 \gg m^2c^4 \quad \Longrightarrow \quad E \sim pc$$

* Examples/discussion