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 $m$: 
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 GeV = 10⁹ eV = energy gained by an electron or proton accelerated through 10⁹ 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

$$E^2 \text{ (in GeV}^2\text{)} = p^2 \text{ (in GeV}^2/c^2\text{)} c^2 + m^2 \text{ (in GeV}^2/c^4\text{)} c^4$$

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?

\[ E^2 = p^2 c^2 + m^2 c^4 \]

\[ p^2 c^2 \gg m^2 c^4 \quad \rightarrow \quad E \sim p c \]

* Examples/discussion