**Measurement of Invariant Mass**

In classical physics the mass of a particle can be determined from its energy, E, and its momentum, p:



The same is true for particles moving with a relativistic velocity, but we must use the correct formula:



The equation ***E*2 = *p*2*c*2 + *m*2*c*4** has two interesting limits:

• For a particle at rest (*p* = 0), it reduces to ***E* = *mc*2**.

• For a highly relativistic particle, *m*2*c*4 << *p*2*c*2, it reduces to *E* = *pc* (which holds true for photons).

The **invariant mass** is a characteristic of the total energy and momentum of an object or a system of objects that is the same in all frames of reference.

Einstein's theory, the invariant mass is a quantity which does not change with velocity or frame of reference. If the units are chosen in such a way that the velocity of light is **c**=1, then the invariant mass is defined as:



Where ***E*** is the total energy of the particles and ***p*** is the momentum.

**Exercise**

Run the following five events on Atlantis:

runNumber="106050" eventNumber="8086"

runNumber="106050" eventNumber="8171"

runNumber="106050" eventNumber="8175"

runNumber="106050" eventNumber="8184"

runNumber="106050" eventNumber="9541"

1. Identify the type of event.
2. Click on the event track, select the data that enables you to determine the invariant mass. Then, determine the average invariant mass of the particle. (Use an excel file)
3. Compare the average invariant mass with the real invariant mass of the particle. If you observe a difference, explain the implications of this difference.

