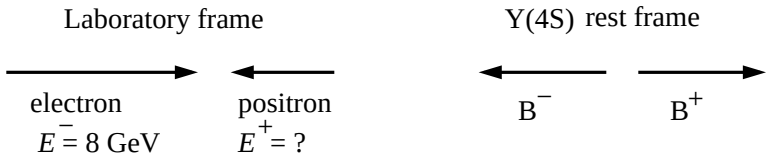
CMA The Japanese B-factory collides electron beams head-on with positron beams. The beam energies are unequal but have been carefully adjusted so as to produce an excited state of the Υ meson called the $\Upsilon(4S)$. The rest mass of the $\Upsilon(4S)$ is 10.58 GeV/c^2. Subsequently the $\Upsilon(4S)$ decays to a pair of B-mesons: B^+ and B^-. The rest masses of the oppositely-charged B^+ and B^- mesons are both 5.28 GeV/c^2. The rest mass of the electron is negligible at these energies.



[Hint: In working the following parts, use units where energy is measured in GeV, momentum in GeV/c, and mass in units GeV/c^2.]

a) The energy of the electron beam is set at $E^- = 8$ GeV and the center of mass energy of the colliding beams is equal to the mass of the $\Upsilon(4S)$. Calculate the energy E^+ of of the positron beam in the laboratory frame. Momenta perpendicular to the beam direction are zero.

b) Calculate the magnitude of the of the momenta of the B^+ and B^- in the *rest frame* of the $\Upsilon(4S)$.

c) Assume the B^+ is emitted in the direction of the electron beam. What are the magnitudes of the 3-momenta of the B^+ and B^- mesons in the laboratory frame?

d) The B^+ and B^- mesons both decay after 1.6×10^{-12} s in their respective rest frames. How far did the B^+ particle travel in the laboratory frame before it decayed?