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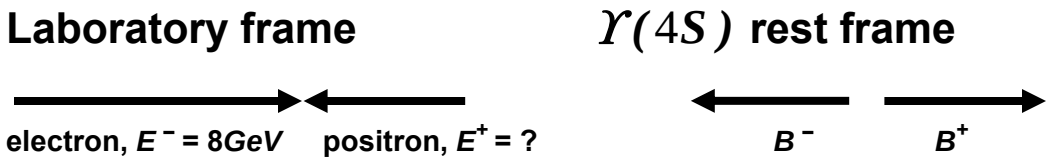
The Japanese B-factory collides electron beams and positron beams with adjustable and unequal beam energies to produce an excited state of the Υ-meson, called the $\Upsilon(4S)$. The rest mass of the $\Upsilon(4S)$ is 10.58 GeV/c^2. Subsequently, the $\Upsilon(4S)$ meson decays into a pair of B-mesons: B^+ and B^-. The rest masses of the oppositely charged B^+ and B^- mesons each are 5.28 GeV/c^2.



Hint: Stay in the units where energy is measured in *GeV*, momentum in *GeV/c* and mass in GeV/c^2.

(a) The beam energy of the electron beam is chosen as $E^- = 8\ GeV$ and the center of mass energy of the colliding beams equals the mass of the $\Upsilon(4S)$ meson: calculate the energy of the positron beam, E^+, in the laboratory frame. Momenta perpendicular to the beam direction are zero.

(b) Calculate the magnitudes of the momenta for the B^+ and B^- mesons 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 for the B^+ and B^- mesons in the laboratory frame?

(d) The B^+ and B^- mesons both decay after $1.6\times10^{-12}s$ in their respective rest frames. How far has each particle traveled in the laboratory frame before they decay?