Answer 1 The CKM element V_{tb} is large (≈ 1), the phase space factor is large, and the W involved is real

Answer 2 The rate is $1.4 \times 10^{34} \times 0.94 \times 10^{-9} times 10^{-24} = 13.16$ pairs per second.

Answer 3 Conservation of energy gives $\sqrt{p^2 + 1869^2} + \sqrt{p^2 + 140^2} = 2010$, where p is the cms momentum (same for D and π). 2010, 1869 a,d 140 are the relevant masses.

Take the second square root to the right hand side and square:
$p^2 + 1869^2 = 2010^2 + p^2 + 140^2 - 2 \times 2010 \times \sqrt{p^2 + 140^2}$

Cancel those p^2 and rearrange to get $p = \sqrt{\left(\frac{2010^2+140^2-1869^2}{2\times2010}\right)^2 - 140^2}$

Which gives $p = 16 MeV/c$

Answer 4 The momentum of the B is given by the same method as question 3, and is $p = \sqrt{\left(\frac{10579^2}{2\times10579}\right)^2 - 5279^2} = \sqrt{5289.5^2 - 5279^2} = 333 MeV/c$

The energy is 10579/2 so the speed is $p/E = 0.063c$

Answer 5

He (or she, or it) is made of antimatter.

In your communications you must have had to define 'right' and 'left', and you will have done so by one key statement of the form 'neutrino spin is anticlockwise along the direction of motion' or equivalent. Then you will have had to explain that anticlockwise is the sequence top-left-bottom-right. He has been using antineutrinos instead of neutrinos and so his definition of left and right is inverted, as antineutrinos spin clockwise.

Answer 6 The b quark has presumably decayed to a $\mu\nu$ though a W, and the W has the same charge as the μ. As $b \to W^- c$ and $\overline{b} \to W^+ \overline{c}$, to get the charges right, this indicates a $\overline{b}$. That means it was a B^0 meson.

Answer 7 The μ^+ could come from a $\overline{b} \to W^+ \overline{c}$ decay but it could also come from a $c \to W^+ s'$ decay, where the c comes from the original b. These 'cascade' decays produce leptons of the 'wrong' sign, but of lower energy as the $c \to s'$ decay has less energy than the $b \to c$ decay.

Answer 8

(1) By measuring the position of the production vertex and the decay vertex, and hance the distance traveled. Also the velocity (through the momentum or from prior knowledge) and then using time = distance / speed.

(2) By tagging the decay using a high momentum lepton (as in Example 6-7) or by an explicit B_s decay or by the charmed meson in the decay (reconstructing a D or a $\overline{D}$)

Answer 9

(1) The mesons are produced in pairs. The high energy lepton tags the far-side meson as a B or $\overline{B}$ meaning that the near-side meson must be a $\overline{B}$ or a B, respectively.

(2) When a B_s is made, a $\overline{b}$ quark combines with an s quark. This s quark must have been plucked out of the vacuum as part of an $s\overline{s}$ pair, leaving an $\overline{s}$ in the jet which can form a K^+, but not a K^-. Hence a nearby K^+ indicates that this is a B_s, likewise a nearby K^- contains an s quark indicating the heavy meson is the $\overline{B}_s$ combination $b\overline{s}$

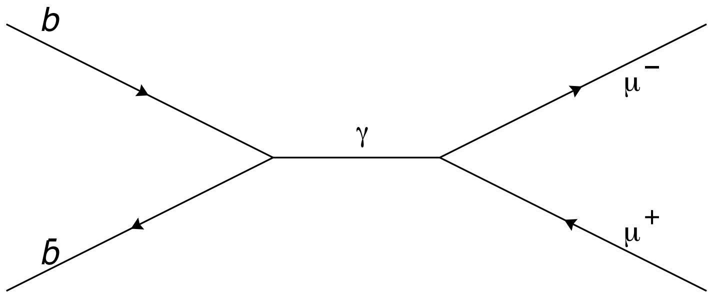
Answer 10

Firstly, PEP-II is not run with enough energy to make $B_s\overline{B}_s$ pairs.

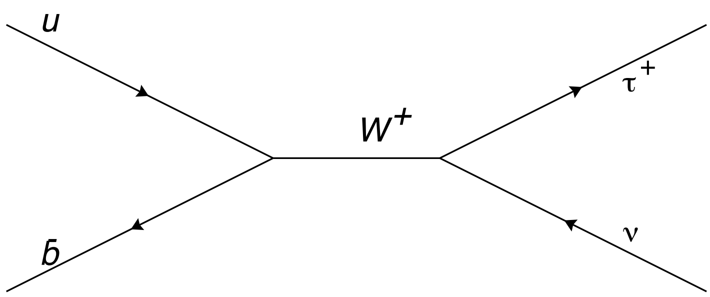
Secondly, even if it did (by running at the $\Upsilon(5S)$, as has been proposed) it only produced $B\overline{B}$ pairs and does not produce jets containing B mesons.

Answer 11

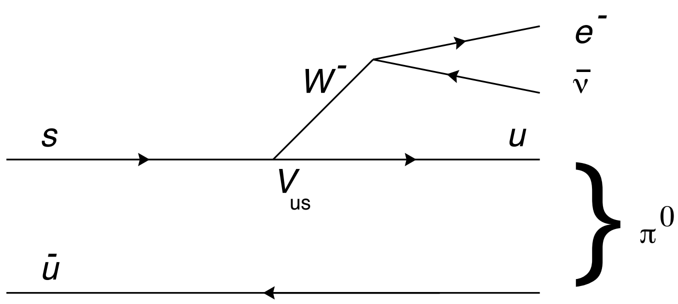
(i) $\Upsilon(4S) \to \mu^+\mu^-$



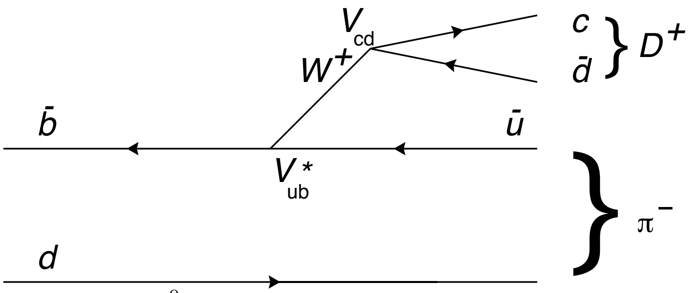
(ii) $B^+ \to \tau^+\nu_\tau$



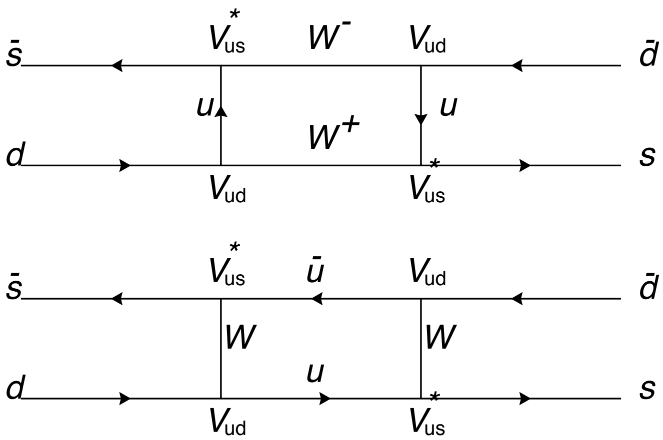
(iii) $K^- \to \pi^0 e^- \overline{\nu}_e$



(iv) $B^0 \rightarrow D^+\pi^-$

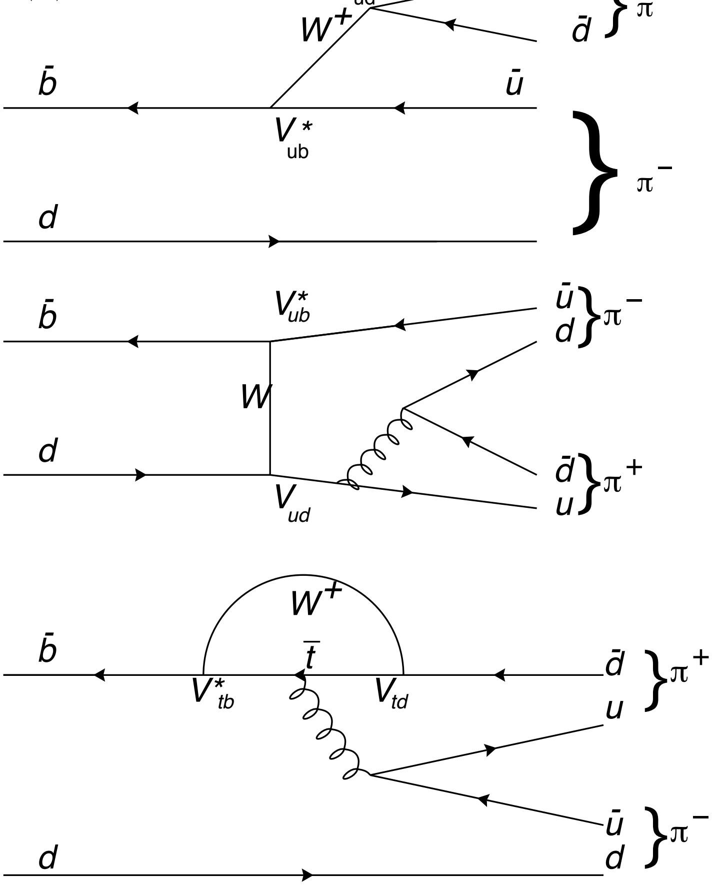


(v) $K^0 \rightarrow \overline{K}^0$



Each of the u quarks may also be a c or a t. So there are actually 18 diagrams. The CKM factors are adjusted appropriately. Don't worry about when to use V and when to use V^*, that's just there for completeness.

(vi) $B^0 \to \pi^+\pi^-$



In the second diagram, the gluon can be emitted from any quark line. In the third (penguin) diagram, the t can also be a c or d, so there are 3 such diagrams (with appropriate CKM factors)

Answer 12

For real rotations, in 4 dimensions there are 16 elements to the matrix but 4+6=10 unitarity equations, leaving 6 'real' rotation angles. (There is one rotation angle for each plane, i.e. for each pair of axes. This is general)

For complex numbers there are $N^2 - (2N - 1) = 16 - (8 - 1) = 9$ parameters. Which is 3 more than 6. So there must be 3 complex phases possible.