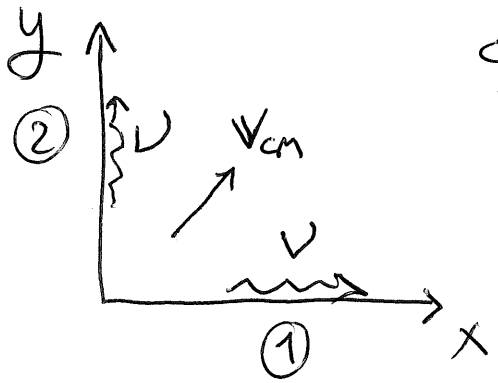
7.7



$c = 1$ units.

$$P^{\mu}_{TOT} = P^{\mu}_{1} + P^{\mu}_{2} = (h\nu, h\nu, 0, 0) + (h\nu, 0, h\nu, 0) = (2h\nu, h\nu, h\nu, 0)$$

$$v_{cm} = \frac{P_{TOT}}{E_{TOT}} = \frac{(h\nu, h\nu, 0)}{2h\nu} = \frac{1}{2}(1, 1, 0)$$

Note that $v_{cm} \cdot v_{cm} = \frac{1}{4}(1+1) = \frac{1}{2} < 1$

$$\Rightarrow E_p = \sqrt{m_p^2 + p^2} = 945 \text{ MeV}$$

$$E_\pi = \sqrt{m_\pi^2 + p^2} = 182 \text{ MeV}$$

$$v_p = \frac{p}{E_p} = 0.124\, c$$

$$v_\pi = -\frac{p}{E_\pi} = -0.641\, c$$