11.19 (a) In the rest frame of the decaying particle, the total 4-momentum before the decay is $p = (M, \vec{0})$. After the decay, due to momentum conservation, we must have, for the two particles, $p_1 = (E_1, \vec{p}_1)$, $p_2 = (E_2, \vec{p}_2)$, with $\vec{p}_1 = -\vec{p}_2$. Since $p = p_1 + p_2$, we have

$(M - E_1, -\vec{p}_1) = (E_2, \vec{p}_2)$. Squaring both sides,

$$(M - E_1)^2 - |\vec{p}_1|^2 = E_2^2 - |\vec{p}_2|^2, \quad \text{or} \quad M^2 - 2ME_1 + E_1^2 - |\vec{p}_1|^2 = E_2^2 - |\vec{p}_2|.$$

Since $m_i^2 = E_i^2 - |\vec{p}_i|^2$, we have $M^2 - 2ME_1 + m_1^2 = m_2^2$, which leads to

$$E_1 = \frac{M^2 + m_1^2 - m_2^2}{2M}$$

Repeat the same procedure for particle 2, we will have

$$E_2 = \frac{M^2 + m_2^2 - m_1^2}{2M}.$$

(b) The kinetic energy for particle i is

$$T_i = E_i - m_i = \frac{M^2 + m_i^2 - m_{-i}^2}{2M} - m_i = \frac{M^2 - 2m_iM + m_i^2 - m_{-i}^2}{2M}$$

$$= \frac{(M - m_i)^2 - m_{-i}^2}{2M} = \frac{(M - m_i - m_{-i})(M - m_i + m_{-i})}{2M}$$

$$= \Delta M \cdot \frac{2M - 2m_i - (M - m_i - m_{-i})}{2M} = \Delta M\left(1 - \frac{m_i}{M} - \frac{\Delta M}{2M}\right).$$

Where $\Delta M = M - m_1 - m_2$.