45. The distance traveled by the pion in the frame of Earth is (using Eq. 38-12) $d = v\,\Delta t$. The proper lifetime Δt_0 is related to Δt by the time-dilation formula: $\Delta t = \gamma \Delta t_0$. To use this equation, we must first find the Lorentz factor γ (using Eq. 38-45). Since the total energy of the pion is given by $E = 1.35 \times 10^5$ MeV and its mc^2 value is 139.6 MeV, then

$$\gamma = \frac{E}{mc^2} = \frac{1.35 \times 10^5\,\text{MeV}}{139.6\,\text{MeV}} = 967.05 \ .$$

Therefore, the lifetime of the moving pion as measured by Earth observers is

$$\Delta t = \gamma \Delta t_0 = (967.1)(35.0 \times 10^{-9}\,\text{s}) = 3.385 \times 10^{-5} \text{ s} \ ,$$

and the distance it travels is

$$d \approx c\Delta t = (2.998 \times 10^8\,\text{m/s})(3.385 \times 10^{-5}\,\text{s}) = 1.015 \times 10^4\,\text{m} = 10.15 \text{ km}$$

where we have approximated its speed as c (note: its speed can be found by solving Eq. 38-8, which gives $v = 0.9999995c$; this more precise value for v would not significantly alter our final result). Thus, the altitude at which the pion decays is $120\,\text{km} - 10.15\,\text{km} = 110\,\text{km}$.