

# Schwartz QFT Solutions

## Chapter 2 – Problem 2.2

Each proton has energy  $E_p = 7$  TeV. Using

$$\frac{v}{c} = \sqrt{1 - \frac{m_p^2 c^4}{E_p^2}}, \quad m_p c^2 = 9.38 \times 10^{-4} \text{ TeV},$$

we get

$$\frac{v}{c} \approx 1 - 9.0 \times 10^{-9}, \quad c - v \approx 2.7 \text{ m/s} \approx 9.7 \text{ km/h}.$$

The relative speed is

$$v_{\text{rel}} = \frac{2v}{1 + v^2/c^2}, \quad \frac{v_{\text{rel}}}{c} = \frac{2\beta}{1 + \beta^2},$$

with  $\beta \approx 1 - 9.0 \times 10^{-9}$ , giving

$$\frac{v_{\text{rel}}}{c} \approx 1 - 1.6 \times 10^{-16}, \quad c - v_{\text{rel}} \approx 4.8 \times 10^{-8} \text{ m/s}.$$