

PHYS 3317 Fall 2012

Exercises on Elementary Particles—Solutions

1. Forbidden reactions

- (a) $p + \bar{p} \rightarrow \mu^+ + e^-$: This reaction is forbidden by conservation of electron *and* muon family numbers.
- (b) $\pi^- + p \rightarrow p + \pi^+$: This reaction is forbidden by conservation of electric charge.
- (c) $p + p \rightarrow p + \pi^+$: This reaction is forbidden by conservation of quark number.
- (d) $p + p \rightarrow p + p + n$: This reaction is forbidden by conservation of quark number.
- (e) $\gamma + p \rightarrow n + \pi^0$: This reaction is forbidden by conservation of electric charge.

2. Energy threshold for reactions

- (a) For the reaction $p + p \rightarrow n + \Sigma^+ + K^0 + \pi^+$, we have

$$\text{KE}_{th} = \frac{(m_n + m_{\Sigma^+} + m_{K^0} + m_{\pi^+})^2 c^2 - (2m_p)^2 c^2}{2m_p}.$$

Plugging in the numbers for the masses gives

$$\text{KE}_{th} = \frac{(939.6 + 1189.4 + 497.7 + 139.6)^2 - (2 \times 938.3)^2}{2 \times 938.3} \text{ MeV} = 2201 \text{ MeV}.$$

- (b) For the reaction $\pi^- + p \rightarrow \Sigma^0 + K^0$, we have,

$$\text{KE}_{th} = \frac{(m_{\Sigma^0} + m_{K^0})^2 c^2 - (m_p + m_{\pi^-})^2 c^2}{2m_p}.$$

Plugging in the numbers for the masses gives

$$\text{KE}_{th} = \frac{(1192.5 + 497.7)^2 - (139.6 + 938.3)^2}{2 \times 938.3} \text{ MeV} = 903 \text{ MeV}.$$

3. Is it possible?

- (a) $\mu^- \rightarrow e^- + \gamma$: Impossible: conservation of electron *and* muon family numbers.
- (b) $p + p \rightarrow \pi^+ + \pi^0$: Impossible: conservation of electric charge.
- (c) $\Sigma^0 \rightarrow \Lambda^0 + \gamma$: Possible: electromagnetic interaction.

- (d) $\Sigma^0 \rightarrow \Lambda^0 + \pi^0$: Impossible: conservation of energy.
- (e) $\Sigma^- \rightarrow n + \pi^-$: Possible: weak interaction.
- (f) $e^- + e^+ \rightarrow \mu^- + \mu^+$: Possible: electromagnetic or weak interaction.
- (g) $\mu^- \rightarrow e^- + \bar{\nu}_e$: Impossible: conservation of muon family number.
- (h) $\Delta^+ \rightarrow p + \pi^0$: Possible: strong interaction.
- (i) $e^- + p \rightarrow \nu_e + \pi^0$: Impossible: conservation of quark number.
- (j) $p + p \rightarrow \Sigma^+ + n + K^0 + \pi^+ + \pi^0$: Possible: strong interaction.
- (k) $p + p \rightarrow p + p + p + \bar{p}$: Possible: strong interaction.
- (l) $\pi^+ + n \rightarrow \pi^- + p$: Impossible: conservation of charge.
- (m) $B^0 \rightarrow \pi^- + p$: Impossible: conservation of quark number.
- (n) $J/\psi \rightarrow \pi^+ + \pi^- + \pi^0 + K^+ + K^-$: Possible: strong interaction.
- (o) $\Upsilon \rightarrow \tau^+ + \tau^-$: Possible: electromagnetic or weak interaction.
- (p) $\Upsilon \rightarrow \tau^+ + \bar{\nu}_\tau$: Impossible: conservation of electric charge.

4. Feynman diagrams

