Na jakou energii je třeba urychlit proton, aby se po srážce s protonem v pevném terči vyprodukoval antiproton?

$$p_1 + p_2 \longrightarrow p_3 + p_4 + \bar{p} + p_5$$

- předpoklad $p_2 = 0$, $p_3 = p_4 = p_5 = \bar{p} = 0$
- invariant $s = (E_{p_1} + E_{p_2})^2 - (\vec{p}_{p_1} + \vec{p}_{p_2})^2 c^2 = (E_{p_3} + E_{p_4} + E_{\bar{p}} + E_{p_5})^2 - (\vec{p}_{p_3} + \vec{p}_{p_4} + \vec{p}_{\bar{p}} + \vec{p}_{p_5})^2 c^2$

$$\Rightarrow (E_{p_1} + m_p c^2)^2 - p_{p_1}^2 c^2 = (4 m_p c^2)^2$$

$$\underline{E_{p_1}^2} + 2E_{p_1} m_p c^2 + m_p^2 c^4 - \underline{p_{p_1}^2 c^2} = 16 m_p^2 c^4$$

$$E_{p_1}^2 - p_{p_1}^2 c^2 = m_p^2 c^4$$

$$\Rightarrow 2E_{p_1} m_p c^2 = 14 m_p^2 c^4$$

$$\underline{E_{p_1} = 7 m_p c^2}$$

$$\rightarrow E_{p_1} = E_{kp_1} + m_p c^2 = 7 m_p c^2 \Leftrightarrow \underline{E_{kp_1} = 6 m_p c^2 \doteq 5630\,\mathrm{MeV}}$$

Jaká kinetická energie je potom potřeba, jestliže se nalétávající proton srazí s protonem v jádře terčíku, který se proti němu pohybuje s kinet. energií 25 MeV?

- podobně jako nahoře, tady ale $0 \neq E_{kp_2} = 25\,\mathrm{MeV}$

$$\Rightarrow 0 \neq \vec{p}_{p_2} \Rightarrow p_{p_2} = -\sqrt{\frac{E_{kp_2}^2 + 2E_{kp_2} E_{0p}}{c^2}}$$

$$\Rightarrow (E_{p_1} + E_{p_2})^2 - \left(p_{p_1} - \sqrt{\frac{E_{kp_2}^2 + 2E_{kp_2} m_p c^2}{c^2}}\right)^2 c^2 = (4 m_p c^2)^2$$

$$\underline{E_{p_1}^2} + 2E_{p_1} E_{p_2} + E_{p_2}^2 - \underline{p_{p_1}^2 c^2} + 2p_{p_1} \sqrt{\frac{E_{kp_2}^2 + 2E_{kp_2} m_p c^2}{c^2}} \cdot c^2 - E_{kp_2}^2 - 2E_{kp_2} m_p c^2 = 16 m_p^2 c^4$$

$$2E_{p_1} E_{p_2} + 2p_{p_1} \sqrt{\frac{E_{kp_2}^2 + 2E_{kp_2} m_p c^2}{c^2}} \cdot c^2 + m_p^2 c^4 + m_p^2 c^4 = 16 m_p^2 c^4$$

$$\Rightarrow E_{p_1} E_{p_2} + p_{p_1} \sqrt{\frac{E_{kp_2}^2 + 2E_{kp} m_p c^2}{c^2}} \cdot c^2 = 7 m_p^2 c^4$$

$$\rightarrow p_{p_1} = \sqrt{\frac{E_{p_1}^2 - m_p^2 c^4}{c^2}}, \quad E_{p_2} = E_{kp_2} + m_p c^2$$

$$\Rightarrow E_{p_1}\left(E_{kp_2} + m_p c^2\right) + \sqrt{E_{p_1}^2 - m_p^2 c^4}\sqrt{E_{kp_2}^2 + 2E_{kp_2} m_p c^2} = 7 m_p^2 c^4$$

$$\left(E_{p_1}^2 - m_p^2 c^4\right)\left(E_{kp_2}^2 + 2E_{kp_2} m_p c^2\right) = 49 m_p^4 c^8 - 14 m_p^2 c^4 \left(E_{kp_2} + m_p c^2\right) E_{p_1} + E_{p_1}^2 \left(E_{kp_2} + m_p c^2\right)^2$$

$$- m_p^2 c^4 E_{p_1}^2 + 14 m_p^2 c^4 \left(E_{kp_2} + m_p c^2\right) E_{p_1} - E_{kp_2}^2 m_p^2 c^4 - 2E_{kp_2} m_p^3 c^6 - 49 m_p^4 c^8 = 0 \;/ :(-m_p$$

$$\underset{A}{\underbrace{1}} E_{p_1}^2 \underbrace{- 14\left(E_{kp_2} + m_p c^2\right)}_{B} E_{p_1} + \underbrace{E_{kp_2}^2 + 2E_{kp_2} m_p c^2 + 49 m_p^2 c^4}_{C} = 0$$

$$\Rightarrow E_{p_1} = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A},$$ smysl dává jenom kořen s $-$

$$\Rightarrow E_{p_1} = \frac{13485{,}75 - 3021{,}15}{2} = 5232{,}3\,\text{MeV}$$

$$\Rightarrow E_{kp_1} = E_{p_1} - m_p c^2 = 5232{,}3\,\text{MeV} - 938{,}27\,\text{MeV} =$$

$$= \underline{\underline{4294{,}03\ \text{MeV}}}$$