... od zadnjič

$$\left[M\left({}^{112}_{48}Cd\right) + M\left({}^{114}_{48}Cd\right)\right]c^2 = \overbrace{(A+1-Z+A-1-Z)}^{2(A-Z)}\, m_n c^2 + 2Z m_p c^2$$

$$- 2w_0 A + 2w_1 A^{\frac{2}{3}} + 2w_2 \frac{Z^2}{A^{\frac{1}{3}}}$$

$$+ 2w_3 \frac{(A-2Z)^2}{A} - 2w_4 \frac{1}{A^{\frac{3}{4}}}$$

$A = 113 \Rightarrow A-1 = 112$

$A + 1 = 114$

↓

to je 2x masa ${}^{113}_{48}Cd$

4. člen $\delta_{ZN}\left({}^{112}_{48}Cd\right) = \delta_{ZN}\left({}^{114}_{48}Cd\right) = -1$

$$\delta_{ZN}\left({}^{113}_{48}Cd\right) = 0$$

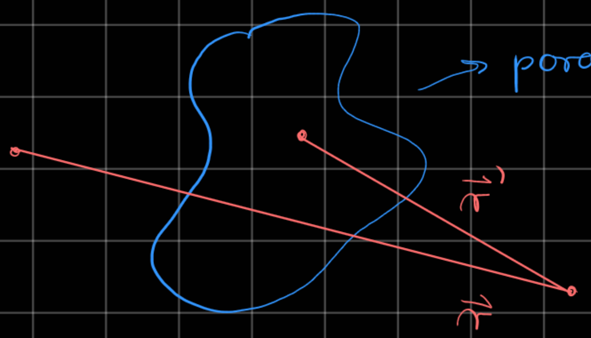
$$= 2M\left({}^{113}_{48}Cd\right)c^2 - 2w_4 \frac{1}{A^{\frac{3}{4}}}$$

Nezname w_0, w_1, w_2, w_3 smo skrili v poznane mase, w_4, ki pa nas zanima pa je izpostavljen

$$w_4 = \frac{\left[2M\left({}^{113}_{48}Cd\right) - M\left({}^{112}_{48}Cd\right) - M\left({}^{114}_{48}Cd\right)\right]c^2 \overset{113}{\overset{\shortparallel}{A}}{}^{\frac{3}{4}}}{2}$$

$$= 43'3\ \mathrm{MeV}$$

Dodatek k predavanju



→ porazdelitev naboja

$\rho(\vec{r}\,')$

$U(\vec r) = ?$

$$U(\vec r) = \frac{1}{4\pi\varepsilon_0} \int \frac{\rho(\vec r)}{|\vec r - \vec r'|} d^3\vec r' \qquad \vec r \gg \vec r'$$

(ta dodatek)

"Ni pomembno, ni za vaje ne za predavanja, ampak prof. je rekel, da moramo narediti" - Daddy Bing

submissive $\oplus \ominus$ $\ominus \oplus$

$\oplus, \ominus$ monopolni prispevek

kvadropolni prispevek

Razvijemo

$$V(\vec r) = \frac{1}{4\pi\varepsilon_0 r} \int \rho(\vec r') \Big[1 - \frac{\vec r \cdot \vec r'}{r} + \overbrace{\frac{1}{2r^2}\left(3(\vec r \cdot \vec r')^2 - \vec r'\right)^2}^{\text{kvadropolni prispevek}} + O\left(\left(\frac{\vec r'}{\vec r}\right)^3\right) \Big] d^3\vec r'$$

dipolni prispevek $\oplus \ominus$

To pride v poštev pri interakciji med snovjo in EM poljem (vpeljava v višjih letnikih)

$\tilde V(t)$

$$\hat H = \frac{\hat p^2}{2m} + V(t) \xrightarrow[\vec p \to \vec p - e\vec A]{} \left(\hat p^2 \left[-2e\hat p \hat A - e^2 \hat A^2\right]\right)/2m$$

vekt. potencial

Verjetnost za prehod

final

$|i\rangle \longrightarrow |f\rangle \quad \propto |\langle f | V_{if} | i \rangle|^2$

initial

dipolni prispevek

$\langle f | \vec E \, \vec\mu_e | i \rangle$

Čopič VI/6 (razširjena naloga)

$$^{235}_{92}U + n \longrightarrow {}^{141}_{55}Cs + {}^{95}_{37}Rb$$

$u = 0{,}940\ GeV/c^2$

$m_n = 1{,}01\,u$

$M(^{235}_{92}U) = 235{,}04\,u$

$M(^{141}_{55}Cs) = 140{,}92\,u$

$M(^{95}_{37}Rb) = 94{,}934\,u$

a) sproščena E, či zanemarimo gibanje reaktantov / produktov?

$$\Delta E = E_k - E_z = \left[\cancel{m_{prod}c^2} + E_{v,p}\right] - \left[\cancel{m_{reak}c^2} + E_{v,r}\right]$$

$\sum m_p + \sum m_n$ $\qquad$ # p^+ in n se ohranja

$m_{prod} = m_{reak}$

$$= E_{v,p} - E_{v,r}$$

SEMF

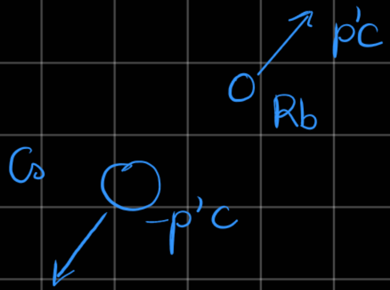
$$E_v(A,Z) = -w_0 A - w_1 A^{\frac{2}{3}} + w_2 \frac{Z^2}{A^{1/3}} + w_3 \frac{(A-2Z)^2}{A} + w_4 \frac{\delta_{ZN}}{A^{3/4}}$$

vzeti splošno vrednosti iz Strnada

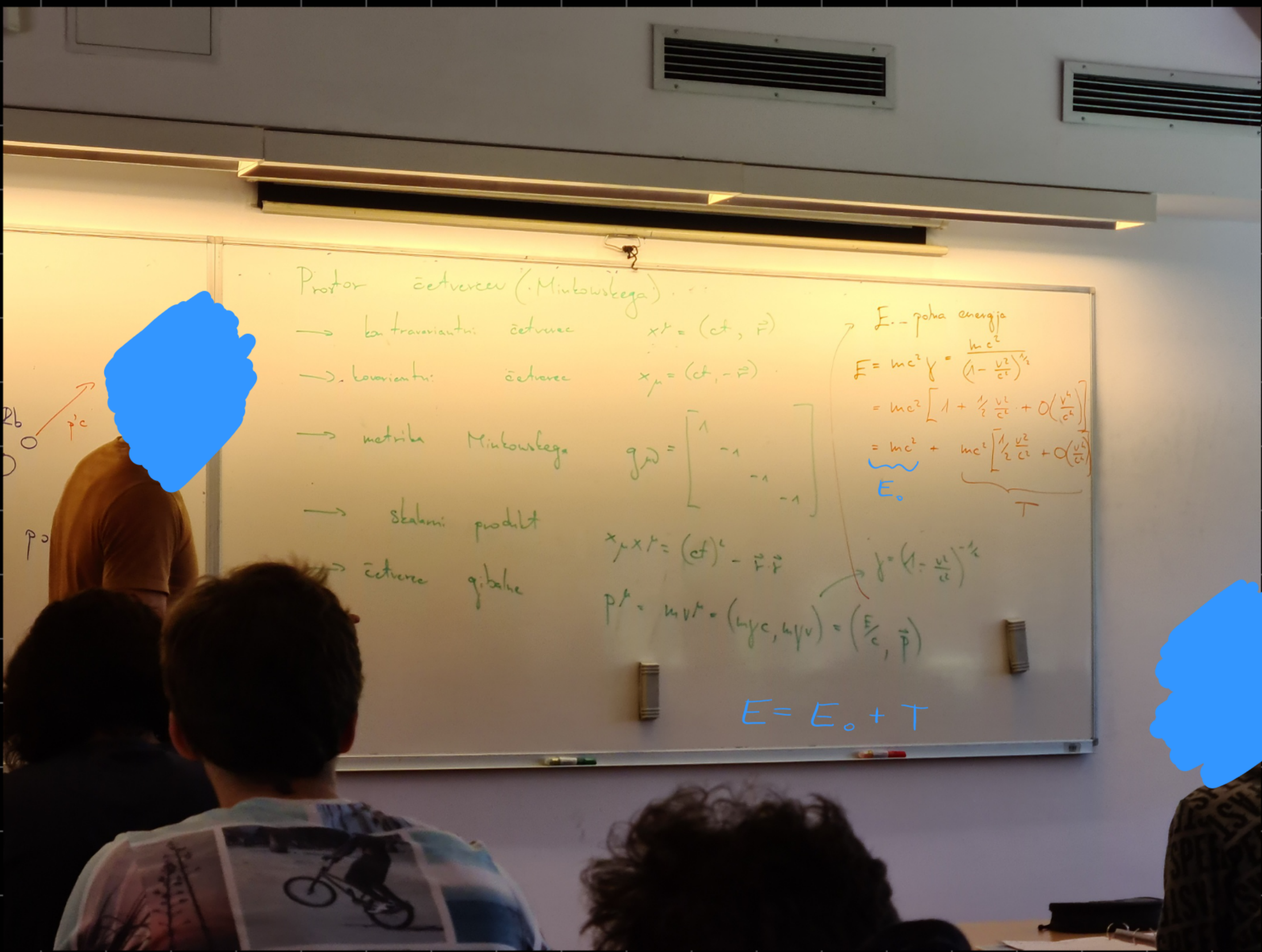
$$= E_v(141,55) + E_v(95,37) - E_v(235,92) = -179{,}7\ MeV$$

b) težiščni sistem, uran in nevtron se gibljeta

$U \xrightarrow{pc} \quad \xleftarrow{-pc} n$ $\qquad$ // pred reakcijo



// po reakciji



Ponovitev MF1

Skalarni produkt se ohranja (rotacija, translacija + še nekaj)

Težiščni sistem $p_{1\mu} c = (\underset{= mc^2}{E^{\mu}}, 0)$

Lab. sistem $p_{2\mu} c = (E, pc)$

$$p_{1\mu} p_{2\mu} = m_e^2 c^4 = E^2 - p^2 c^2$$

$$\Rightarrow E = \sqrt{(mc^2)^2 + p^2c^2}$$

$p_0 c = 500\ \text{MeV}$

Zamenja mas

$p'c = ?$

$T_{Cs} = ?$

$T_{Rb} = ?$

- pred

$$\left.\begin{aligned} p_U^\mu c^2 &= (E_U, p_0 c) \\ p_m^\mu c^2 &= (E_m, -p_0 c) \end{aligned}\right\} \quad p_z^\mu c^2 = (\underbrace{E_U + E_m}_{E^* \ldots\ \text{težiščna energija}}, 0)$$

$$E^* = \underbrace{\sqrt{(m_U c^2)^2 + (p_0 c)^2}}_{E_U} + \underbrace{\sqrt{(m_m c^2)^2 + (p_0 c)^2}}_{E_m} = 220'0\ \text{GeV}$$

- po reakciji

$$\left.\begin{aligned} p_{Rb}^\mu c^2 &= (E_{Rb}, p^2 c) \\ p_{Cs}^\mu c^2 &= (E_{Cs}, -p^2 c) \end{aligned}\right\} \quad p_K^\mu c^2 = (E_{Rb} + E_{Cs}, 0)$$

Pogledamo ohranitev energije

$$p_x^\mu c = p_K^\mu c$$

Da bo reakcija mogoča, more veljati $E^* > m_{Rb}c^2 + m_{Cs}c^2$

$$E^* = E_{Rb} + E_{Cs} = T_{Rb} + m_{Rb}c^2 + T_{Cs} + m_{Cs}c^2 = \cancel{\alpha}$$

$$T = E - E_0 = \sqrt{(mc^2)^2 + (pc)^2} - mc^2$$

$$= mc^2\left[\sqrt{1 + \left(\frac{pc}{mc^2}\right)^2} - 1\right]$$

hitrost delcev

$pc << mc^2 \Rightarrow$ nerelativistični

mirovne mase približek

$$\approx mc^2\left[1 + \frac{1}{2}\left(\frac{pc}{mc^2}\right)^2 - 1\right] = \frac{1}{2}\frac{(pc)^2}{mc^2}$$

$$\cancel{\alpha} = \frac{1}{2}\frac{(p'c)^2}{m_{Rb}c^2} + m_{Rb}c^2 + \frac{1}{2}\frac{(p'c)^2}{m_{Cs}c^2} + m_{Cs}c^2$$

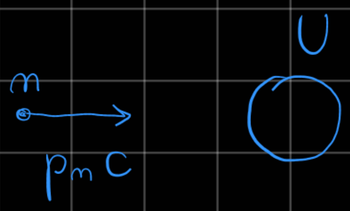
Izrazimo $p'c$: $$p'c = \left(\frac{2\left[E - (m_{Rb} + m_{Cs})c^2\right]}{\frac{1}{m_{Rb}c^2} + \frac{1}{m_{Cs}c^2}}\right)^{\frac{1}{2}} = 5'63\ \mathrm{GeV}$$

$$T_{Rb} = \frac{1}{2}\frac{(p'c)^2}{m_{Rb}c^2} = 179\ \mathrm{MeV}$$

$$T_{Cs} = \frac{1}{2}\frac{(p'c)^2}{m_{Cs}c^2} = 121\ \mathrm{MeV}$$

c) Laboratorijski sistem z mirujočim uranom

$E_U = ?$ $\quad p_n c = ?$



Zapišimo četverca

$$\left.\begin{aligned} p_n^\mu c &= (E_n, p_n c) \\ p_U^\mu c &= (E_U, \emptyset) \end{aligned}\right\} p_z^\mu c = (E_n + E_U, p_n c)$$

$$\underbrace{(p_T^\mu c)(p_{T\mu} c)}_{\text{težiščni}} = \overbrace{(p_L^\mu c)(p_{L\mu} c)}^{\text{laboratorijski}}$$

$$\Downarrow$$

$$E^{*2} = (E_n + E_U)^2 - (p_n c)^2$$

$$E^{*2} = E_n^2 + 2 E_n E_U + E_U^2 - (p_n c)^2$$

Razpišimo z invariantami $E = \sqrt{(mc^2)^2 + (pc)^2}$

$$E_n = \sqrt{(m_n c^2)^2 + (p_n c)^2}$$

$$E_U = m_U c^2$$

$$E^{*2} = (m_n c^2) + \cancel{(p_n c)^2} + (m_U c^2)^2 + 2 m_U c \sqrt{(m_n c^2)^2 + (p_n c)^2} - \cancel{(p_n c)^2}$$

$$p_n c = \left(\frac{E^{*2} - (m_n c^2)^2 - (m_U c^2)^2}{2 m_U c^2} - (m_n c^2)^2 \right)^{\frac{1}{2}} = 0'49\,\mathrm{GeV}$$

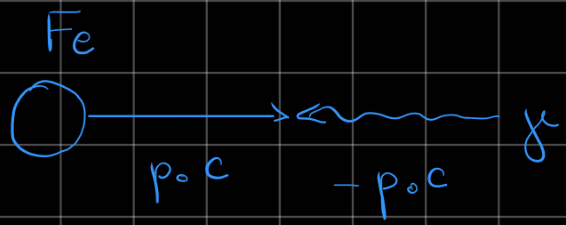
$$E_n = \sqrt{(m_n c^2)^2 + (p_n c)^2} = 1'06\,\mathrm{eV}$$

Plinski model se ne dela (bo pri FJODu)

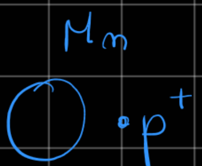
VI/8

a) $\gamma + {}^{56}_{26}\mathrm{Fe} \longrightarrow {}^{1}_{1}p + {}^{55}_{25}\mathrm{Mn}$

Zanima na $E_\gamma^{min} = ?$



//pred reakcijo



$v_{Mn} = v_p = 0 \quad |\vec{p}| = \emptyset$

1) $p^\mu_{Fe} c = (E_{Fe}, p_0 c)$

$p^\mu_\gamma c = (p_0 c, -p_0 c)$

$\searrow$ E brezmasnega delca

$$\left.\right\} p_1^\mu c = (E_{Fe} + p_0 c, \emptyset)$$

2) $p^\mu_{Mn} c = (m_{Mn} c^2, \emptyset)$

$p^\mu_{p^+} c = (m_p c^2, \emptyset)$

$$\left.\right\} p_2^\mu c = (m_{Mn} c^2 + m_p c^2, \emptyset)$$

a) $p_1^{\mu} c = p_2^{\mu} c$ Ohranitev E in GK

$$E_{Fe} + p_0 c = m_{Mn} c^2 + m_p c^2$$

$$\sqrt{(m_{Fe} c^2)^2 + \cancel{(p_0 c)^2}} + p_0 c = m_{Mn} c^2 + m_p c^2$$

zanemarimo E_γ^2, saj vemo, da je $|E_v(Fe) - E_v(Mn)| \ll E$

To pomeni, da je potrebna E_γ za tak prehod $\sim E_0$ in zato majhna

$$\underbrace{p_0 c}_{= E_{\gamma min}} = m_{Mn} c^2 + m_p c^2 - m_{Fe} c^2$$

// po aproksimaciji dobimo ravno razliko mirovnih energij

$$M(A,Z) c^2 = \underbrace{(A-Z) m_n c^2}_{} + \underbrace{Z m_p c^2}_{} + E_v(A,Z)$$

produkti # n^0 in p^+ == # n^0 in p^+ reaktantov, se odšteje

$$\Rightarrow E_{\gamma min} = E_v(Mn) - E_v(Fe) = \underbrace{E_v(55, 25)}_{-482'17 \text{ MeV}} - \overbrace{E_v(56, 26)}^{-491'61 \text{ MeV}} = 9'50 \text{ MeV}$$

$\downarrow$ SEMF $(w_0, w_1, w_2, w_3, w_4)$

b) Kolikšna je $E_{\gamma min}$, da izbije n^0? $\gamma + {}^{56}_{26}Fe \rightarrow {}^{1}_{0}n + {}^{55}_{25}Fe$

$\hookrightarrow E_\gamma^{min}(b) = 12'11$ MeV