Неделя 11.

Релятивистские и нерелятивистские столкновения частиц.

Динамика релятивистских частиц.

018

$k_1 = 1$ эВ

$K_2 = 1$ МэВ

$W_0 = mc^2 \approx 0{,}5$ МэВ

$$p = \frac{m v_1}{\sqrt{1-\frac{v^2}{c^2}}} \qquad k = pc$$

1) $k_1 = p_1 c = \dfrac{m \cdot v_1 c}{\sqrt{1-\frac{v_1^2}{c^2}}}$; $k_1^2\left(1-\dfrac{v_1^2}{c^2}\right) = m^2 v_1^2 c^2$

$$v_1^2\left(m^2c^2 + \frac{k_1^2}{c^2}\right) = k_1^2$$

$$\underline{\underline{v_1}} = \sqrt{\frac{k_1^2}{m^2c^2+\frac{k_1^2}{c^2}}} = c\sqrt{\frac{k_1^2}{m^2c^4+k_1^2}} = c\sqrt{\frac{k_1^2}{W_0^2+k_1^2}} = \underline{\underline{6 \cdot 10^5 \ \frac{м}{с}}}$$

2) $$\underline{\underline{v_2 = c\sqrt{\frac{k_2^2}{W_0^2+k_2^2}} = 2{,}8 \cdot 10^8 \ \frac{м}{с}}}$$

019

^{139}Cs

$E = 1$ МэВ

$$m_{Cs} = m$$

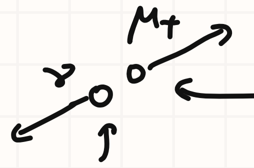
$$\underset{W}{\underset{\shortparallel}{mc^2}} + E = k = pc = \frac{mvc}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$(W+E)^2\left(1-\frac{v^2}{c^2}\right) = m^2c^2v^2$$

$$v^2\left(m^2c^2 + \frac{(W+E)^2}{c^2}\right) = (W+E)^2$$

$$\underline{\underline{v}} = c\sqrt{\frac{(W+E)^2}{W^2+(W+E)^2}} = \underline{\underline{2{,}3 \cdot 10^5 \ м/с}}$$

8.44



π^+

π^+-мезон

$m_\pi c^2 = 139{,}6$ МэВ

$= W_{p\pi}$

антимюон

$m_\mu c^2 = 105{,}7$ МэВ

$= W_{p\mu}$

нейтрино

энергия покоя $= 0$

$= W_{p\nu}$

$K_\mu - ?$

$K_\nu - ?$

(кинетические энергии продуктов распада)

(ЗСИ)

$$\vec{p}_\nu = -\vec{p}_{\mu+}$$

(ЗСЭ)

$$W_{p\pi} = \underbrace{W_{p\nu}}_{0} + W_{p\mu} + K_\mu + K_\nu$$

$$K_\nu = p_\nu \cdot c \ ; \ p_\nu = \frac{K_\nu}{c}$$

$$p_\mu = \frac{m_\mu v_1}{\sqrt{1-\frac{v_1^2}{c^2}}} \ ; \ K_\mu = \frac{m_\mu c^2}{\sqrt{1-\frac{v_1^2}{c^2}}} - W_{p\mu} \ ; \ v_1 = c\sqrt{1-\left(\frac{m_\mu c^2}{K_\mu + W_{p\mu}}\right)^2}$$

$$p_\mu = \frac{m_\mu c\sqrt{1+\left(\frac{m_\mu c^2}{K_\mu+W_{p\mu}}\right)^2}}{\frac{m_\mu c^2}{K_\mu+W_{p\mu}}} = \frac{K_\mu + W_{p\mu}}{c}\sqrt{1+\left(\frac{\overset{W_{p\mu}}{m_\mu c^2}}{K_\mu+W_{p\mu}}\right)^2}$$

$$p_\mu = -p_\nu$$

(ЗСИ)

$$\frac{K_\mu + W_{p\mu}}{\cancel{c}}\sqrt{1-\left(\frac{W_{p\mu}}{K_\mu+W_{p\mu}}\right)^2} = -\frac{K_\nu}{\cancel{c}}$$

(ЗСЭ)

$$\underbrace{W_{p0}} = K_\nu + K_\mu + \underbrace{W_{p\mu}}$$

$$K_\nu = W_{p0} - W_{p\mu} - K_\mu$$

$$K_\mu^2 + \cancel{W_{p\mu}^2} + 2K_\mu \cdot W_{p\mu} - \cancel{W_{p\mu}^2} = K_\nu^2$$

$$K_\mu^2 + 2W_{p\mu}K_\mu - K_\nu^2 = 0$$

подставим

$$\cancel{K_\mu^2} + \cancel{2W_{p\mu}K_\mu} - (W_{p0} - W_{p\mu})^2 - \cancel{K_\mu^2} + 2(W_{p0} - \cancel{W_{p\mu}})K_\mu = 0$$

$$2W_{p0}K_\mu = (W_{p0} - W_{p\mu})^2$$

$$K_\mu = \frac{(W_{p0} - W_{p\mu})^2}{2W_{p0}} = \underline{\underline{4{,}1 \text{ МэВ}}}$$

$$K_\nu = W_{p0} - W_{p\mu} - \frac{(W_{p0} - W_{p\mu})^2}{2W_{p0}} = (W_{p0} - W_{p\mu})\left(\frac{\cancel{2}W_{p0} - \cancel{W_{p0}} + W_{p\mu}}{2W_{p0}}\right) =$$

$$= \frac{W_{p0}^2 - W_{p\mu}^2}{2W_{p0}} = \underline{\underline{29{,}8 \text{ МэВ}}}$$

8.57

$K^+ \longrightarrow \pi^+ + \pi^0$

$\pi^0 \longrightarrow \gamma + e^+ + e^-$

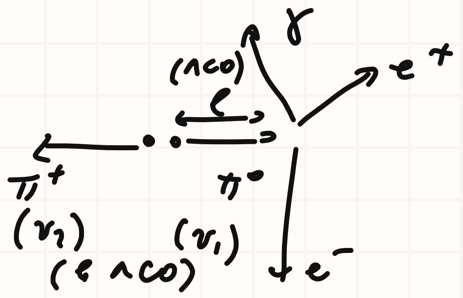
$\ell = 0{,}38$ мкм

$\tau_0 - ?$ (π^0)

$W_0 = M_K c^2 = 494$ МэВ

$W_2 = M_{\pi^+} c^2 = 140$ МэВ

$W_1 = M_{\pi^0} c^2 = 135$ МэВ



$$\underset{\text{лсо}}{\tau_0} = \frac{\ell}{v_1}$$

$$\underset{(\text{с со } \pi^0)}{\tau_0} = \underset{\text{лсо}}{\tau_0} \sqrt{1 - \frac{v_1^2}{c^2}} = \frac{\ell}{v_1} \sqrt{1 - \frac{v_1^2}{c^2}}$$

осталось найти $v_1 \rightsquigarrow$ ЗСИ + ЗСЭ

(ЗСИ) $p_1 + p_2 = 0$

(ЗСЭ) $W_0 = K_1 + K_2 + W_1 + W_2$

$$p_i = \frac{k_i + W_i}{c} \sqrt{1 - \left(\frac{W_i}{k_i + W_i}\right)^2}$$

$$W_0 - (k_1 + W_1) = k_2 + W_2 = \frac{E_2}{\sqrt{1 - \frac{v_2^2}{c^2}}} \; ; \quad k_1 + W_1 = \frac{W_1}{\sqrt{1 - \frac{v_1^2}{c^2}}}$$

применим ЗСИ:

$$\frac{W_1}{\sqrt{1-\beta_1^2}} \sqrt{1 - \sqrt{1-\beta_1^2}} + \frac{W_2}{\sqrt{1-\beta_2^2}} \sqrt{1 - \sqrt{1-\beta_2^2}} = 0$$

$$\frac{W_1^2}{1-\beta_1^2} \left(1 - \sqrt{1-\beta_1^2}\right) = \frac{W_2^2}{1-\beta_2^2} \left(1 - \sqrt{1-\beta_2^2}\right)$$

$$\frac{W_1}{\sqrt{1-\beta_1^2}} = \frac{W_0^2 + W_1^2 - W_2^2}{2W_0}$$

$$v_1 = c\sqrt{1 - \left(\frac{2W_0 W_1}{W_0^2 + W_1^2 + W_2^2}\right)^2} = \underline{\underline{0{,}835c}}$$

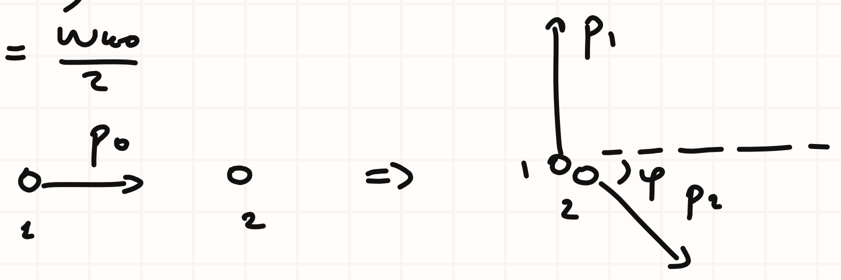
$$\tau_0 = \frac{\ell}{v_1}\sqrt{1-\beta_1^2} = \frac{\ell}{c\sqrt{1 - \left(\frac{2W_0 W_1}{W_0^2 + W_1^2 + W_2^2}\right)^2}} \cdot \frac{2W_1 W_2}{W_0^2 + W_1^2 - W_2^2} = \underline{\underline{8{,}4 \cdot 10^{-16}}}$$

8.105

$v = 2{,}6 \cdot 10^{8}$ м/с
(вдоль x)
$W_{k1} = \frac{W_{k0}}{2}$

$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$

$\beta = \frac{v}{c}$



(ЗСИ)

$p_0 = p_2 \cos\varphi$

$p_1 = p_2 \sin\varphi$

(ЗСЭ)

$W_{k0} + W_{p1} + W_{p2} = W_{k1} + \overset{W_{p1}}{\overset{\parallel}{W'_{p1}}} + W_{k2} + \overset{W_{p2}}{\overset{\parallel}{W'_{p2}}}$

$W_{k1} = \frac{W_{k0}}{2}$ (из усл.)

$W_{k0} = W_{k1} + W_{k2} = \frac{W_{k0}}{2}$; $W_{k2} = \frac{W_{k0}}{2}$

Так, $W_{k1} = W_{k2} = \frac{W_{k0}}{2}$

$$(W_{k0} + W_{p1})^2 - W_{p1}^2 + (\underset{\frac{1}{2}W_{k0}}{\underset{\parallel}{W_{k1}}} + W_{p1})^2 - W_{p1}^2 = (\underset{\frac{1}{2}W_{k0}}{\underset{\parallel}{W_{k2}}} + W_{p2})^2 - W_{p2}^2$$

$$W_{k0}^{\cancel{2}} + 2\cancel{W_{k0}}W_{p1} + \cancel{\tfrac{1}{4}W_{k0}^2} + \cancel{W_{k0}}W_{p1} = \cancel{\tfrac{1}{4}W_{k0}^2} + \cancel{W_{k0}}W_{p2}$$

$$W_{k0} + 3W_{p1} - W_{p2} = 0$$

// $p_1^2 c^2 = (W_{k1} + W_{p1})^2 - W_{p1}^2$; $p_1 = \frac{\sqrt{(W_{k1} + W_{p1})^2 - W_{p1}^2}}{c}$ //

$$\frac{m_н c^2}{\sqrt{1 - \frac{v^2}{c^2}}} + 2m_н c^2 = mc^2$$

$$m = 2m_н + \frac{m_н}{\sqrt{1-\frac{v^2}{c^2}}} \approx \underline{\underline{4m_н}}$$

T.9

$l = 1m$ $\quad k = \sigma A = FL$ $\quad \vec{F} \parallel \vec{v}$

$\tau = 5{,}8\ nc$ $\quad F = \gamma^3 m \frac{dv}{dt}$

W_k – ?

$W_p = mc^2$

$$\frac{W_k}{mc^2} = \frac{\frac{\cancel{mc^2}}{\sqrt{1-\beta^2}} - \cancel{mc^2}}{\cancel{mc^2}} = \frac{1}{\sqrt{1-\beta^2}} - 1 =$$

$$\frac{F}{m}\int_0^\tau dt = \int_0^{V_k} \frac{dV}{\left(1-\frac{v^2}{c^2}\right)^{3/2}}$$

$$\frac{k\tau}{Lm} = c\int_0^{\beta_k} \frac{d\beta}{(1-\beta^2)^{3/2}} = c\frac{\beta_k}{\sqrt{1-\beta^2}}$$

$$k = \frac{Lmc\beta_k\gamma_k}{\tau} = \varepsilon_0(\gamma_k - 1) = \frac{mc^2}{1}(\gamma_k - 1)$$

$$\beta_k = \frac{\tau c(\gamma_k - 1)}{L\gamma_k} \ ; \quad \gamma_k = \frac{1}{\sqrt{1-\beta_k^2}}$$

$$\beta_k = \frac{\tau c\left(1-\sqrt{1-\beta_k^2}\right)}{L} = \frac{\tau c - \tau c\sqrt{1-\beta_k^2}}{L} = \frac{\tau c}{L}\left(1-\sqrt{1-\beta_k^2}\right)$$

$$\tau c - L\beta_k = \tau c\sqrt{1-\beta_k^2}$$

$$\cancel{\tau^2 c^2} + L^2\beta_k^2 - 2\tau c L\beta_k = \cancel{\tau^2 c^2} - \tau^2 c^2\beta_k^2$$

$$\beta_k\left((L^2 + c^2\tau^2)\beta_k - 2c\tau L\right) = 0$$

$$\beta_k = \frac{2Lc\tau}{L^2 + c^2\tau^2} \approx 0{,}864$$

$$\frac{W_k}{mc^2} = \frac{1}{\sqrt{1-\beta^2}} - 1 \approx 1$$