(2) $\lambda \sim \frac{h}{p}$

$A \sim \frac{\hbar}{\lambda}$ ~~10^{-16} eV/s~~

$$p = \frac{h}{\lambda} = \frac{\hbar c}{\lambda c}\cdot 2\pi = \frac{200\,\mathrm{MeV\,fm}}{0.8\,\mathrm{fm}\,c}\,2\pi = 1570\,\frac{\mathrm{MeV}}{c} \sim E_e$$

(5)

$$E_f + mc^2 = E_f' + E_p \qquad E_p = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} \sim mc^2 + \frac{1}{2}mv^2$$

$$p_f = p_f' + p_p \qquad p_f^2 = p_f'^2 + p_p^2 + 2p_f' p_p \qquad \frac{1}{2}\,\mathrm{GeV}\,\frac{v^2}{c^2} = 5\,\mathrm{MeV}$$

$$E_f = E_f' + \frac{1}{2}mv^2 \qquad \frac{E_f^2}{c^2} = \frac{E_f'^2}{c^2} + \frac{m^2v^2}{1-\frac{v^2}{c^2}} + 2\frac{E_f'}{c}\,mv\cdot\cos\theta$$

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

(6)

~~$E_\gamma + \ldots = E_\gamma' + E_k\;\frac{p^2}{2(14m)}\ldots = E_\gamma' + \sqrt{2\cdot 14m_p\cdot p}$~~

$p_\gamma = E_\gamma = p - E_\gamma' = \sqrt{2E_k\cdot 14\cdot m_p} - E_\gamma'$ imp

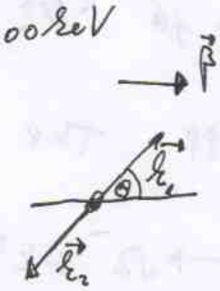
$E_\gamma = E_\gamma' + E_k$ energia

$E_k \ll E_\gamma$

$$\left(2E_\gamma - E_k\right)^2 = 2E_k\,14\,\overset{1\,\mathrm{GeV}}{m}$$

$$4E_\gamma^2\left(1 - \frac{E_k}{2E_\gamma}\right)^2 = 4E_\gamma^2\left(1 - \frac{E_k}{E_\gamma}\right) = 2E_k\cdot 14m \qquad E_k \sim 400\,\mathrm{keV}$$

(7) $\quad p_0^\mu = \begin{pmatrix} m_\pi \\ 0 \end{pmatrix} = \begin{pmatrix} \omega_1 + \omega_2 \\ \vec{k}_1 + \vec{k}_2 \end{pmatrix} \qquad \omega = \frac{m}{2}$



$$\omega^l = \frac{1}{\sqrt{1-\beta^2}}\left(\omega + \omega\beta\cos\theta\right) = \frac{\omega}{\sqrt{1-\beta^2}}\left(1+\beta\cos\theta\right)$$

~~$\sin\theta = \sqrt{1 - (\omega^l A - B)^2}$~~

$$\frac{dN}{d\cos\theta} = \mathrm{konst} = \frac{dN}{d\omega^l}\cdot\frac{d\omega^l}{d\cos\theta} = \frac{dN}{d\omega^l}\cdot\frac{(\omega\beta)}{\sqrt{1-\beta^2}}$$

~~$\sin\theta$~~ $\qquad \frac{dN}{d\omega^l} \sim \frac{1}{\sqrt{1-(\omega^l A - B)^2}}$

$= \frac{dN}{d\omega^l}$ const egyenletes

nyílásszög

$$\mathrm{tg}\,\theta' = \frac{k'_y}{k'_x} = \frac{\omega\sin\theta}{\frac{1}{\sqrt{\;}}(\omega\beta + \omega\cos\theta)}$$

(9) $\frac{1}{2}mv^2=\frac{3}{2}kT$ $v=\sqrt{\frac{3kT}{m}}$ $\frac{mv^2}{3k}=T$

(10) $p\,(\mathrm{GeV}/c) = 0.3\,B\cdot\rho\ (\mathrm{Tm})$

(11) $\frac{dp}{dt}=F$ $\underbrace{\Delta\frac{m\,v_x}{\sqrt{1-\frac{v_x^2+v_y^2}{c^2}}}}_{\Delta(M v_x)} = F\cdot t^{\text{áthaladási idő}}$

ha nem-rel $M=m$, ha ultra rel v_x-et elhanyagolják $\frac{m}{\sqrt{1-\frac{v_y^2}{c^2}}}$

proton 100 MeV : NR 10 GeV, 1000 GeV : UR

e^--ra ? jó az UR?

(13) $e^{-\frac{t}{\tau}} = e^{-\frac{t}{\tau_0}\sqrt{1-\frac{v^2}{c^2}}} = e^{-\frac{t}{\tau_0}}$

$L = v\cdot\frac{\tau_0}{\sqrt{1-\frac{v^2}{c^2}}}$ $\cancel{m}$ $= E_\mu$ $\overset{\approx p_\pi}{E_\pi} = E_\mu + E_\nu$

$p_\pi = p_\mu + p_\nu$ vagy $p_\pi = p_\nu - p_\mu$

$p_\nu = 0$ vagy 100 GeV

(14) Kaonn $m_K \gg m_\pi$ bomláskor, mintha két tömeg nélküli bomlana: egyenletes spektrum

pionnál tulán jó a NR

(15) $pp \to p\bar{p}\,pp$ TKP rsz

(16) $K^- + p \to \Omega^- + K^+ + K^0$

$u\bar{s}$ uud sss $u\bar{s}$ $d\bar{s}$

(17) $e^+e^- \to \bar{p}\,p$

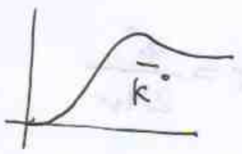
$e^+e^- \to \Omega^-\,(\Omega^-)^{\text{anti}}$

sss

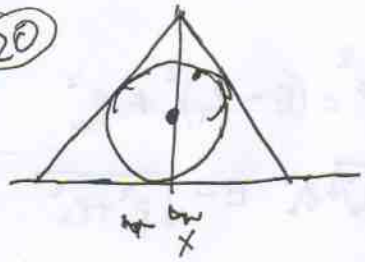
1,5 GeV

(18) magtömeg = Barion szám − kötési Vas magokat

(19) $|\psi\rangle_0 = |K_0\rangle = \dfrac{|K_L\rangle + |K_S\rangle}{\sqrt{2}} \longrightarrow \dfrac{1}{\sqrt{2}}\, |K_L\rangle \cdot e^{-i m_L t - \frac{\Gamma_L}{2} t} + \dots$



(20)



$T_{\pi^-} = R + 4 \qquad T_{\pi^+} =$

$\sqrt{T_3} = \sqrt{T_1} + \sqrt{T_2} \qquad T_3 = T_1 + T_2 + 2\sqrt{T_1 T_2}$

$Q - 2(T_1 + T_2) = 2\sqrt{T_1 T_2}$

$\sqrt{\frac{Q}{3} - r\cos\varphi}$

$T_{1,2} = \frac{Q}{3}\left(1 + r\cos\left(\frac{2}{3}\pi \pm \varphi\right)\right) = \frac{Q}{3}\left(1 - r\frac{\cos\varphi}{2} \mp r\frac{\sqrt{3}}{2}\sin\varphi\right)$

$T_3 = \frac{Q}{3}(1 + r\cos\varphi)$

$\cancel{Q} - 2\frac{2\cancel{Q}}{3}\left(1 - r\frac{\cos\varphi}{2}\right) = \frac{\cancel{Q}}{3} 2\sqrt{\left(1 - r\frac{\cos\varphi}{2}\right)^2 - \frac{3}{4}r^2\sin^2\varphi}$

$-\frac{1}{\cancel{3}} + \frac{2r}{\cancel{3}}\cos\varphi = \frac{2}{\cancel{3}}\sqrt{\underbrace{1 + r^2\frac{1}{4}\cos^2\varphi - r\cos\varphi - \frac{3r^2}{4}\sin^2\varphi}_{r^2\cos^2\varphi - r\cos\varphi + 1/4}}$ ← ha $r = 1$

$1 + 4r^2\cos^2\varphi - 4r\cos\varphi = 4r^2\cos^2\varphi - 4r\cos\varphi + 1$ ✓

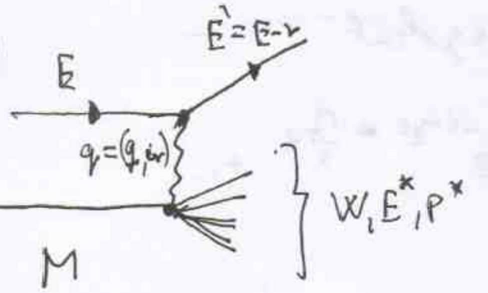
21. $\sqrt{(T_3 + m_3)^2 - m_3^2}$

$\sqrt{T_3^2 + 2T_3 m_3} = \sqrt{T_2^2 + 2T_2\cdot m} + \sqrt{T_1^2 + 2T_1 m}$

23. ellipszis

$r = \dfrac{a(1-e^2)}{1 + e\cos\varphi}$

(24)

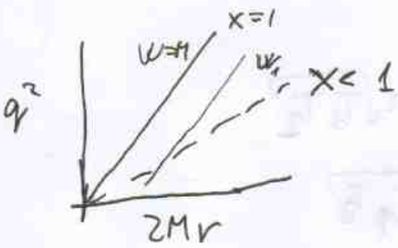


$$q^2 = (p^* - 0)^2 - (E^* - M)^2$$

$$\nu = E^* - M \qquad W^2 = E^{*2} - p^{*2}$$

~~q~~ elasztikus, ha $W = M$

$$q^2 = 2M\nu - W^2 + M^2$$, elasztikus eset $q^2 = 2M\nu$ $\qquad x = \frac{q^2}{2M\nu}$



θ

$m_e \approx 0$

$$\sin\theta = \frac{p_\perp}{E'} \qquad p^{*2} = (E - p_\parallel)^2 + p_\perp^2$$

$$\cos\theta = \frac{p_\parallel}{E - \nu} \qquad \nu = \sqrt{p_\parallel^2 + p_\perp^2} \quad E - \sqrt{p_\parallel^2 + p_\perp^2}$$

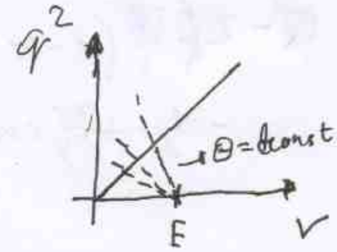
$$p^{*2} = E^2 - 2Ep_\parallel + (\cancel{\nu} + E)^2 = E^2 - 2E(E-\nu)\cos\theta + (E-\nu)^2$$

$$= 2E^2(1-\cos\theta) + 2E\nu(\cos\theta - 1) + \nu^2$$

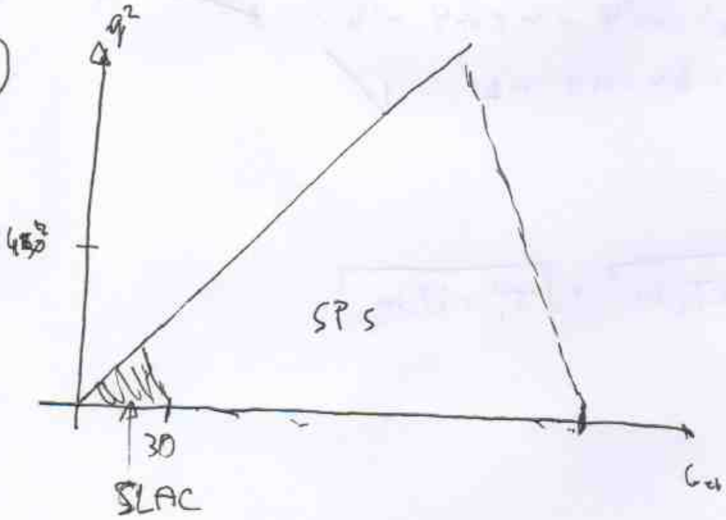
$$= 2E(E-\nu)(1-\cos\theta) + \nu^2$$

$$p^{*2} = \underbrace{(M+\nu)^2 - W^2}_{q^2 + \nu^2} = 2E(E-\nu)(1-\cos\theta) + \nu^2$$

$$q^2 = 2E(E-\nu)(1-\cos\theta)$$



(25)



HERA

$$\cancel{E^2 + M^2} =$$

$$s^2 = (E+M)^2 - E^2 = (E_e + E_p)^2 - (E_p - E_e)^2$$

$$M^2 + 2ME = \cancel{2(E_e^2 + E_p^2)} + 4E_eE_p$$

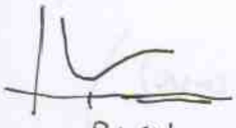
$$E = \frac{2 \cdot 4 E_e E_p}{M} = 2\cdots$$

26

29.

BB: $-\frac{dE}{dx} = K \frac{z^2}{\beta^2} \frac{Z}{A} \left[\ln \frac{2 m_e c^2 \beta^2}{I(1-\beta^2)} \right\} - \beta^2 \Big]$ $K \approx 0.3\ \mathrm{MeV} \cdot \frac{cm^2}{g}$

$-\left(\frac{dE}{dx}\right) \sim \frac{1}{\beta^2} \ln(\beta\gamma)$



$\beta\gamma \approx 4$

b) $-\left(\frac{dE}{dx}\right) \approx 2\ \mathrm{MeV}/\mathrm{cm}$ $d = 5\ m$

c) $d = 50\ m$

a, $T_1 = 1\ \mathrm{MeV}$ $V^2 = \frac{2T_1}{m_p} = 0.02$ $\frac{dE}{dx} \sim \frac{1}{V^2} \approx 100\ \frac{\mathrm{MeV}}{cm}$

$d \approx 0.1\ mm$

28 erre mondjuk elvileg nem jó a BB... relativisztikus ??? eltekintve $\frac{dE}{dx} \sim 2\ \mathrm{MeV}/cm$

32

33 $N = 2^t$ $E = \frac{E_0}{2^t}$ $t = \frac{\ln \frac{E_0}{E_c}}{\ln 2}$ E_c : ionizáció dominál

$E_c \sim \frac{600\ \mathrm{MeV}}{Z}$, rendszám

vízre : 60 MeV

$\Delta x = Z \cdot t = Z \cdot 4 \approx 150\ cm$

35 $E = \frac{E_0}{2^t}$ $t = \frac{\ln \frac{E_0}{E_c}}{\ln 2}$ E_c: bejövő hadron tömege?

3 el. pion $p = \frac{h}{\lambda} = \frac{200\ \mathrm{MeV\,fm}}{0.65\ \mathrm{fm}\, c} 2\pi = 1930\ \mathrm{MeV}/c$

~~$p_\mu^2 = (E_e + m_\pi)^2 - E_e^2 = m_\pi^2 + 2m_\pi E = E_\pi^2$~~ mozgó pion

Tk p számít (??)

$s^2 = p^2 = (E_\pi + m_e)^2 - p_\pi^2 = m_\pi^2 + 2E_\pi m_e$ $E_\pi = 3.7\ \mathrm{TeV}$

⑦ folytatás (szöger)

$$\cos\Theta' = \frac{\vec{k}_1' \vec{k}_2'}{\omega_1' \omega_2'} \approx \frac{1}{1-\beta^2\cos^2\Theta}\cdot\left(-\sin^2\Theta + \frac{1}{1-\beta^2}\cdot\left(\beta^2 - \cos^2\Theta\right)\right)$$

$$k_x' = \frac{\omega}{\sqrt{}}(\beta + \cos\Theta)$$

$$= \frac{1}{1-\beta^2\cos^2\Theta}\left(\frac{-1+\beta^2(\sin^2\Theta+1)}{1-\beta^2}\right) \approx \frac{-1+\beta^2+\beta^2\sin^2\Theta}{1-\beta^2\cos^2\Theta}$$

$\Theta = \frac{\pi}{2}$ -nél van a min. nyílásszög

$\boxed{14}$

$$E_{\pi/K} = E_\mu + E_\nu \qquad \sqrt{E^2 - m_{\pi/K}^2} = \sqrt{E_\mu^2 - m_\mu^2} - E_\nu$$

$$E + \sqrt{E^2 - m_{\pi/K}^2} = E_\mu + \sqrt{E_\mu^2 - m_\mu^2}$$

$$E_\mu = \frac{E m_\mu^2 + E m_{\pi/K}^2 - m_\mu^2\sqrt{E^2 - m_{\pi/K}^2} + m_{\pi/K}^2\sqrt{E^2 - m_{\pi/K}^2}}{2 m_{\pi/K}^2}$$

$$\sqrt{E^2 - m^2} = E_\nu + \sqrt{E_\mu^2 - m_\mu^2}$$

$$E - \sqrt{E^2 - m^2} = E_\mu - \sqrt{E_\mu^2 - m^2}$$