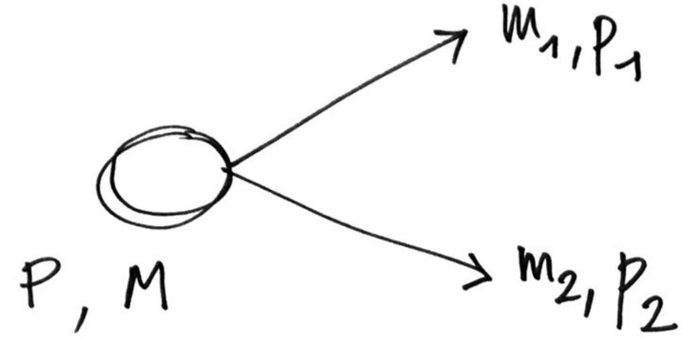

$H \to \gamma\gamma$

$(\gamma \to e^+e^-)$

$Z \to e^+e^-$

$\pi^- \to \mu^- \bar{\nu}_\mu$

$$P = (E, \vec{p})$$

$$P = (M, \vec{\emptyset})$$

$$p_1 = (E_1, \vec{p}_1)$$

$$P = p_1 + p_2$$

$$(P - p_1)^2 = p_2^2$$

$$P^2 + p_1^2 - 2P\cdot p_1 = p_2^2$$

$$M^2 + m_1^2 - 2ME_1 = m_2^2$$

$$\boxed{E_1 = \frac{M^2 + m_1^2 - m_2^2}{2M}}$$

$m_1 = m_2$

$$E_1 = E_2 = \frac{M}{2}$$

$$E^2 = m^2 + p^2$$

$$p_1^2 = E_1^2 - m_1^2$$

$$p_1 = \sqrt{\frac{(M^2 + m_1^2 - m_2^2)^2}{4M^2} - m_1^2}$$

$$\lambda = \frac{h}{p} = \frac{2\pi \underbrace{\hbar c}}{pc}$$

$\hbar c =$ 😃

$197 \text{ fm} \cdot \text{MeV}$

$10^{-15} \text{m} \cdot 10^{6} \text{eV}$

$$pc = \frac{2\pi \hbar c}{\lambda} = \frac{\overset{1.2 \cdot 10^{3}}{2\pi \, 197} \cdot 10^{-9} \, \cancel{\text{m}} \cdot \text{eV}}{10^{-10} \, \cancel{\text{m}}}$$

ATOM

$$= 1.2 \cdot 10^{4} \text{eV}$$

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

$$E_\pi = m_\pi = 140\ \text{MeV} \qquad m_2 = 0$$

$$m_\mu = 105\ \text{MeV}$$

$$m_\nu = 0 \quad \cancel{1\ \text{eV}} \qquad p_1 = \frac{M^2 - m_1^2}{2M}$$

$$p_\mu = \frac{140^2 - 105^2}{2 \cdot 140}\ \text{MeV} \cong 30.63\ \text{MeV}$$

$$H \rightarrow ZZ^* \rightarrow \overbrace{\underbrace{\mu^+\mu^-}_{m_Z} e^+ e^-}^{m_H}$$

$$\sqrt{s} \geq \sum_i m_i$$

$$\pi + p \longrightarrow \pi + \pi + \pi + p$$

$$3m_\pi + m_p$$

$$\sqrt{s} = \sqrt{\left(\sum_i E_i\right)^2 - \left(\sum_i \vec{p}_i\right)^2}$$

$m_\pi = 140\,\text{MeV}$

$\boxed{m_p = 938\,\text{MeV} \\ 1\,\text{GeV}}$

$$(E_\pi, \vec{p}_\pi) \qquad (m_p, \vec{\emptyset})$$

$$s = (E_\pi + m_p)^2 - |\vec{p}_\pi|^2 \geq (3m_\pi + m_p)^2$$

$$E_\pi^2 + \cancel{m_p^2} + 2E_\pi m_p - \cancel{p_\pi^2} \geq 9m_\pi^2 + \cancel{m_p^2} + 6m_\pi m_p$$

$$m_\pi^2 + \cancel{p_\pi^2}$$

$$m_\pi^2 + 2E_\pi m_p \geq 9m_\pi^2 + 6m_\pi m_p$$

$$E_\pi \geq \frac{\overset{4}{\cancel{8}}\, m_\pi^2 + \overset{3}{\cancel{6}}\, m_\pi m_p}{\cancel{2}\, m_p} = \begin{cases} 0.5\,\text{GeV} \\ 441\,\text{MeV} \\ 503\,\text{MeV} \end{cases}$$

$$S = \left(\sum_i E_i\right)^2 - \left(\sum_i \vec{p}_i\right)^2$$

$$p + \gamma \rightarrow \Delta^+ \leftarrow m_{\Delta^+} = 1.2\,\text{GeV}$$

$$E_\gamma = 10^{-3}\,\text{eV}$$

$$\sqrt{S} \geqslant m_{\Delta^+}$$

$$S \geqslant m_{\Delta^+}^2$$

$$(E_p + E_\gamma)^2 - (\vec{p}_p + \vec{E}_\gamma)^2$$

$$E_p^2 + \cancel{E_\gamma^2} + 2E_pE_\gamma - \cancel{p_p^2} - \cancel{E_\gamma^2} - 2\,\vec{p}_p\cdot\vec{E}_\gamma$$

$$m_p^2 + \cancel{p_p^2}$$

$$m_p^2 + 2E_pE_\gamma - 2\,E_\gamma|\vec{p}_p|\cos\theta$$

$$E_p \sim |\vec{p}_p|$$

$$m_p^2 + 2E_pE_\gamma(1-\cos\theta) \geqslant m_{\Delta^+}^2$$

$$m_p = 10^9\,\text{eV}$$

$$m_{\Delta^+} = 1.2\cdot 10^9\,\text{eV}$$

$$E_p \geqslant \frac{m_{\Delta^+}^2 - m_p^2}{2E_\gamma(1-\cos\theta)} \;\boxed{\theta = \pi}\; = \frac{m_{\Delta^+}^2 - m_p^2}{4E_\gamma} = \frac{1.4\cdot 10^{18} - 10^{18}\,\text{eV}^2}{4\cdot 10^{-3}\,\text{eV}}$$

$$\frac{\cancel{4}\cdot 10^{17}\,\text{eV}^{\cancel{2}}}{\cancel{4}\cdot 10^{-3}\,\cancel{\text{eV}}} = 10^{20}\,\text{eV} = 10^{11}\,\text{GeV}$$

$$\sigma(t\bar{t}) \sim 800\,pb = 800\cdot 10^{-12}\,10^{-24}\,cm^2$$

$$\mathcal{L} = 10^{34}\,cm^{-2}s^{-1}$$

$$N_{t\bar{t}} = 10^{34}\,\cancel{cm^{-2}}\,s^{-1}\cdot 8\cdot 10^{-34}\,\cancel{cm^{2}} = 8\,s^{-1}$$

$$=$$

$$3,15\cdot 10^{17} \qquad 2.5\cdot 10^{8}\ t\bar{t}/y$$

$m_1, \vec{p}_1$ $\qquad$ m_2, ϕ

$$(E_1+m_2)^2-(p_1)^2$$

$$E_1^2+m_2^2+2E_1m_2-\cancel{p_1^2}$$

$$m_1^2+\cancel{p_1^2}$$

$$2E_1m_2+m_1^2+m_2^2$$

$$2E_{fix}\,m+2m^2$$

m_1 $\quad$ $\vec{p}_1$ $\quad$ $\vec{p}_2 = -\vec{p}_1$ $\quad$ m_2

$$(E_1+E_2)^2$$

$$(2E_{coll})^2$$

$$4E_{coll}^2$$

$$=$$

$$E_{fix} = \frac{2E_{coll}^2-m^2}{m}$$

$$m_1=m_2=m$$

$$E_{LHC} = 7\ TeV$$

$$E_{fix} = \frac{2(7\,TeV)^2}{1\,GeV} - 1\,GeV$$

$$= \frac{2\cdot 7^2\cdot 10^6\,GeV^{\cancel{2}}}{\cancel{1\,GeV}} =$$

$$\simeq 10^8\,GeV$$

$$= \boxed{10^5\,TeV}$$

1) 5.4 T
2) 0.8 T
3) 9 T
4) 8 T

$L = 27$ km $\quad R = 4.3$ km

$$\Delta E = \frac{4\pi}{3} \frac{\hbar c \, e^2}{4\pi \varepsilon_0 \hbar c} \left(\frac{\beta^3 \gamma^4}{R} \right)$$

$$\frac{e^2}{4\pi \varepsilon_0 \hbar c} = \alpha = \frac{1}{137}$$

$$\frac{4\pi}{3} \cdot \underbrace{\hbar c}_{197 \text{ fm} \cdot \text{MeV}} \overset{\frac{1}{137}}{\alpha} \left(\frac{\beta^3 \gamma^4}{R} \right)$$

$\boxed{E = 50 \text{ GeV}}$ $50 \cdot 10^9$ $5 \cdot 10^{10}$

$$\gamma = \frac{E}{m} = \frac{50 \text{ GeV}}{0.5 \text{ MeV}} = 10^5 \longleftrightarrow \beta \sim 1$$

$0.5 \cdot 10^6$
$5 \cdot 10^5$

$$\frac{4\pi}{3} \cdot \frac{197}{137} \, 10^{-15} \cancel{m} \text{ MeV} \left(\frac{10^{20}}{4.3 \cdot 10^3 \cancel{m}} \right) \simeq 2 \cdot 10^5 \cdot 10^{-3} \text{ MeV}$$

$$= \boxed{2 \cdot 10^2 \text{ MeV}}$$

$\beta \cong 1 \qquad c = 3 \cdot 10^8\ m/s$

$L = 27 \cdot 10^3\ m \qquad cT = L$

$$f = \frac{1}{T} = \frac{c}{L} = \frac{\cancel{3} \cdot 10^8\ m/s}{\cancel{2.7} \cdot 10^4\ m} \simeq 10^4\ s^{-1}$$

1s $\quad \Delta E(1s) = 10^4\ s^{-1} \cdot 200\ MeV/s$

$= \boxed{2 \cdot 10^6\ MeV/s}$

$$\gamma = \frac{E}{m}$$

$$\frac{\Delta E_e}{\Delta E_p} = \left(\frac{\gamma_e}{\gamma_p}\right)^4 = \left(\frac{m_p}{m_e}\right)^4 = \left(\frac{1\ GeV}{0.5\ MeV}\right)^4$$

$= (2 \cdot 10^3)^4 =$

$= 16 \cdot 10^{12} =$

$= \boxed{1.6 \cdot 10^{13}}$