Particle Physics 1 : Exercise 2

1) Navigation in the PDG booklet ...

1⟩ 1 fm^{-1} = 197.3269788 MeV

2⟩ $M_{\text{sun}} = 1.9885 \times 10^{30}$ kg

? $H_0 =$

3⟩ Gauge and Higgs bosons

γ : mass $< 1.10^{-18}$ eV charge $< 1.10^{-35}$ eV

Z : mass $(91.1876 \pm 0.0021$ GeV) decay rate $\Gamma_Z = 2.4952$ GeV

Higgs ← H^0 : mass (125.09 ± 0.24) GeV

Bohr Magneton

4⟩ Leptons

~ attosecond (10^{-18} s)

e^- : Lifetime $> 4.6 \times 10^{26}$ as magnetic moment $\mu = 1.001159 \ldots \mu_B$

τ : mass $= 1776.86$ MeV $\Gamma_\tau = 2.267 \times 10^{-3}$ eV

main decay modes in leptons : $\tau^- \to e^- \bar{\nu}_e \nu_\tau$ (17.83%)

in hadrons : $\tau^- \to \pi^- \pi^0 \nu_\tau$ (25.52%)

μ : main decay modes $\mu^- \to e^- \bar{\nu}_e \nu_\mu$

? fraction $\mu \to e\gamma$ $< 5.7 \times 10^{-13}$

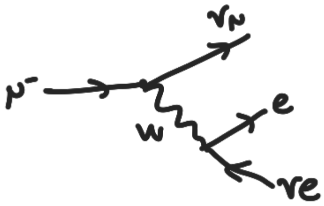
ν : ? numbers of neutrinos mass < 2 eV

magnetic moment $< 0.29 \times 10^{-10}\ \mu_B$

5⟩ Quarks

Quarks masses

u	1.8 – 3.0 MeV	d	4.5 – 5.3 MeV
c	1.275 ± 0.025 GeV	s	95 ± 5 MeV
t	$173.21 \pm 0.51 \pm 0.71$ GeV	b	4.66 ± 0.03 GeV



6⟩ Mesons

$\pi^+ = u\bar{d}$

$\pi^- = d\bar{u}$

$\pi^0 = u\bar{u}, d\bar{d}$

$K^+ = u\bar{s}$

$K^0 = d\bar{s}$

$\bar{K} = s\bar{u}$

$B^+ = u\bar{b}$

$B^- = b\bar{u}$

$\omega(782) = \frac{u\bar{u} + d\bar{d}}{\sqrt{2}}$

$\pi^\pm$ $I(J^P) = 1(0^-)$ main decay modes : $\pi^+ \to \mu^+ \nu_\mu$

with a photon : $\pi^+ \to \mu^+ \nu_\mu \gamma$

π^0 $I(J^P) = 1(0^-)$ main decay mode : $\pi^0 \to \gamma\gamma$

$\omega(782)$ $I(J^P) = 0(1^-)$ $S = 0$ main decay mode :

$K^\pm$ $I(J^P) = \frac{1}{2}(0^-)$ $S = \pm 1$ main decay mode :

K^0 $M = 497$ MeV $\tau = 0.8953 \times 10^{-10}$

$B^\pm$ $I(J^P) = \frac{1}{2}(0^-)$ $S = 0$ $B^t = \pm 1$ $C = 0$ $T = 0$ $M = 5279.15$ MeV main decay mode : $B^+ \to \bar{D}^*(2007)^0 \ell^+ \nu_\ell$ (6.5) % ?

7⟩ Baryons

p uud $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ $S = 0$ $M = 938.272$ MeV $\tau > 2.1 \times 10^{29}$ ans ?

uuu $\Delta(1232)$ $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$ $S = 0$ $M = 1231$ MeV $\Gamma = 116 - 120$ MeV

sss Ω^- $I(J^P) = 0(\frac{3}{2}^+)$ $S = -3$ $M = 1672$ $\Gamma = 8.02 \times 10^{-6}$ eV

I → isospin

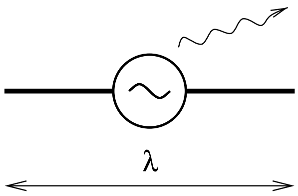
B → baryon number

J → total angular momentum

P → parity

C → C-parity

2) Planck Mass



An electric dipole (∼antenna) emits oscillations with a wavelength λ. The dipole has an energy that allows the emission of at least one photon γ of the energy :

$$E_\gamma = \frac{hc}{\lambda}.$$

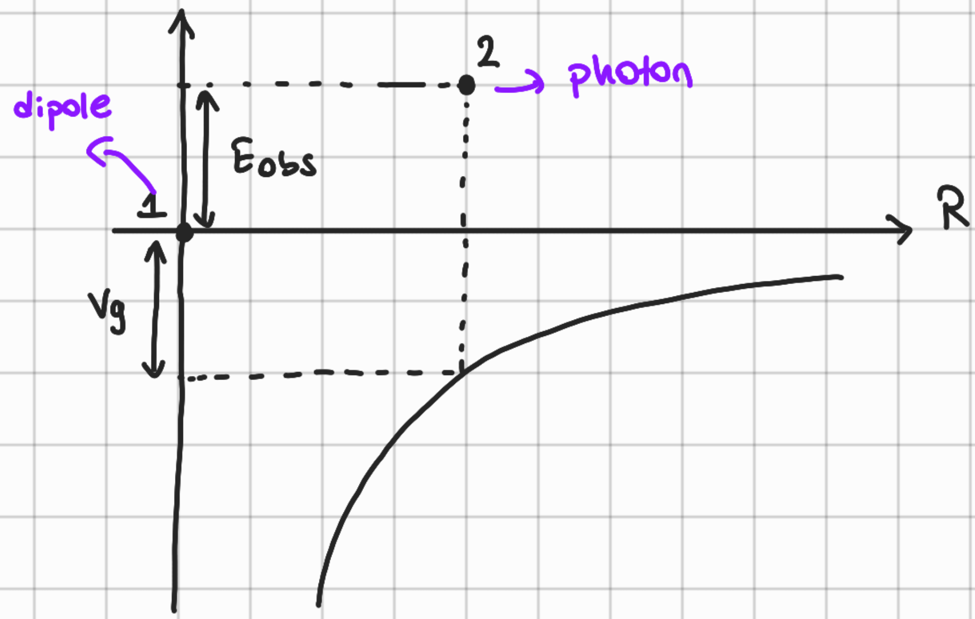
Suppose, that the photon has a virtual mass of $m_{\text{photon}} = m_{\text{dipole}}$. Estimate the energy, which is necessary in order that the photon remains trapped under the gravitational potential generated by the dipole. ($E_\gamma = h\nu(\lambda)$)

From that determine the result for Planck mass : $m_P = \sqrt{\frac{hc}{G}}$.

3) Rutherford cross section

In the lecture you computed the full Rutherford scattering cross section. Compute the relative fraction of α-particles scattering at the angle $\Theta > \Theta_0 = \pi/2$ for an experiment using platinum foil with a thickness of $\delta = 8 \cdot 10^{-5}$ cm. The average energy of the α-particles is 6 MeV, the platinum density is $\rho = 21.5$ g/cm^3, the charge is Z=78 and the mass is A = 195 ($N_A = 6 \cdot 10^{-23}$mole^{-1}). Consider that α-particles interact only once.

Exercise 1 Planck Mass



$$V_g = -G\frac{m_1 m_2}{R}$$

potential energy of photon in the field of gravity of the mass of dipole

$$E_\gamma = E_{\gamma,\,emission} > |V_g| \Rightarrow E_{obs} = E_\gamma - |V_g|$$

To photon remain trapped

$$\Downarrow$$

$$E_{obs} = E_\gamma - |V_g| = 0$$

$$E_\gamma = |V_g|$$

given $M_{photon} = M_{dipole}$

$$\frac{hc}{\lambda} = G\frac{M_{dipole} M_{photon}}{R} = G\left[\frac{hc}{\lambda c^2}\cdot\frac{hc}{\lambda c^2}\right]\frac{1}{\lambda}$$

$$\cancel{\frac{hc}{\lambda}} = G\,\frac{h^{\cancel{2}}\,\cancel{c^2}}{\lambda^2 c^{\cancel{4}3}}\cdot\frac{1}{\cancel{\lambda}}$$

$$\lambda^2 = \frac{Gh}{c^3}$$

$$E = mc^2 = \frac{hc}{\lambda} \rightsquigarrow \lambda = \frac{h}{mc}$$

$$\frac{h^{\cancel{2}}}{m^2\cancel{c^2}} = \frac{G\cancel{h}}{c^{\cancel{3}}}$$

$$m^2 = \frac{hc}{G} \rightarrow \boxed{M_P = \sqrt{\frac{hc}{G}}}$$

Exercise 3 : Rutherford Cross Section

3) Rutherford cross section

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cross section

$$\sigma = 4\pi \left(\frac{2 Z e^2}{4 E_{kin}} \right)^2 \cot(\Theta/2)^2$$

\# of targets: $\dfrac{N_A \, \delta \, \rho}{A \times 10^{-3}\,\text{kg}}$

flux

\# of targets per kg

$(1u \cdot N_A = 1 \frac{g}{mol})$

Incident particle rate $= \dfrac{\Delta N}{\Delta t}$ → Rate per unit area $\dfrac{\Delta N}{\Delta t a}$

Fraction scattered $= \dfrac{R_s}{R_i} =$ flux × cross section

$$\frac{R_s}{R_i} = \left(\frac{N_A \, \delta \rho}{A \times 10^{-3}} \right) \times \left(4\pi \left(\frac{2 Z e^2}{4 E_{kin}} \right)^2 \cot\left(\frac{\Theta}{2}\right)^2 \right)$$

$$= \frac{6 \times 10^{23} \,(1/\text{mol}) \;\; 8 \times 10^{-7}\,\text{m} \times 21500\,\text{kg/m}^3}{195 \times 10^{-3}\,\text{kg/mol}} \times 4\pi \left(\frac{2 \times 78 \, e^2}{4 \times 6\,\text{MeV}} \right)^2 \cot^2\left(\frac{\pi/2}{2}\right)$$

$$\left.\begin{aligned} 1/\text{eV} &= 1.97 \times 10^{-7}\,\text{m} \\ e^2 &= 1/137 \end{aligned}\right\} \text{with natural units } (\hbar = c = 1)$$