QM 115B Lec 26

Nuclear Scattering

$$V(r) = \beta \frac{e^{-\mu r}}{r} \qquad \beta \approx \# \hbar c$$

$$\hbar c \sim [E\,L]$$

$$\mu \sim \frac{1}{[L]} \sim \frac{[E]}{\hbar c}$$

$$\mu = \frac{m_\pi c^2}{\hbar c} \qquad \frac{135\,\text{MeV}}{6.58\times10^{-16}\,\text{eVs}\ 3\times10^{8}\,\text{m/s}} = 1.4\times10^{-15}\,\text{m}$$

$$k \to 0 \quad \sigma = \frac{16\pi m^2 \beta^2}{\hbar^4 \mu^4}$$

$$\simeq \frac{16\pi m_N^2 (\hbar c)^2}{\hbar^4 \left(\frac{m_\pi c}{\hbar}\right)^4} \qquad \frac{16\pi\,(980\,\text{MeV})^2\,\hbar^2 c^2}{(135\,\text{MeV})^4}$$

$$= 5.7\times10^{-27}\,\text{m}^2$$

57 barns

Neutrino Elastic Scattering

$$V_{weak}(r) = \pm \beta_W e^{-\mu_W r}$$

$$\mu_W = \frac{M_Z c^2}{\hbar c} = \frac{90 \text{ GeV}}{\hbar c}$$

$$= \frac{1}{2 \times 10^{-18} \text{ m}}$$

relativistic $E \sim \text{MeV} \gg m_\nu c^2$

$$\hbar k c \sim \text{MeV}$$

$$k \sim \frac{\text{MeV}}{\hbar c} \ll \mu_W$$

low energy

$$\sigma \simeq \frac{16\pi \left(\frac{E}{c^2}\right)^2 \beta_W^2}{\hbar^4 \mu^4}$$

$$\simeq \frac{16\pi E^2 (\hbar c \alpha g^2)^2}{\hbar^4 \left(\frac{M_Z^4 c^8}{\hbar^4 c^4}\right)}$$

$$\simeq \frac{16\pi E^2 \alpha^2 c^2 \hbar^2 g^4}{(M_Z c^2)^4}$$

$E = 1 \text{MeV}$ $\quad \sigma \simeq g^2 \, 10^{-48} \text{ m}^2$

exp $\sigma \simeq 10^{-47} \text{ m}^2$

Mean Free Path in Lead

$$L = \frac{1}{n \cdot \sigma} = \frac{1}{\left(\frac{11400\,kg}{m^3}\ \frac{1}{1.66\times10^{-27}kg}\right)10^{-4?}m}$$

$\frac{\#}{Vol} \cdot area$

$$= 1.5\times10^{16}\,m = 1.6 \text{ light years}$$

Water $L = \frac{1}{n \cdot \sigma} = \frac{1}{\frac{1000\,kg}{m^3\ 1.66\times10^{-27}kg}\Big)\ 10^{-47}m^2}$

$$= 1.7\times10^{17}\,m \approx 18 \text{ light years}$$

Sun $p + p \rightarrow D + e^+ + \nu_e$

$p + p + e^- \rightarrow D + \nu_e$

on Earth $\mathcal{L} = \frac{6\times10^{10}\,\nu}{cm^2\ s}$ $\quad E_{ave} \approx .26\,MeV$

for 3 tons of water

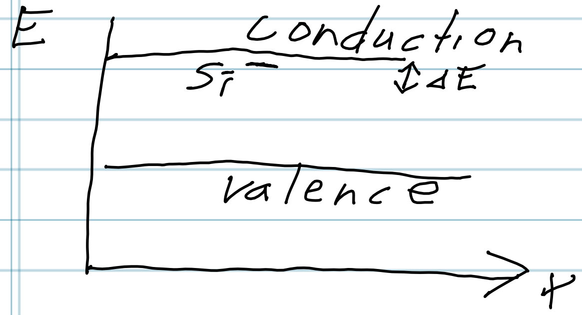
Rate $= \mathcal{L} \cdot \sigma \cdot n_{targets}$

$$= \frac{6\times10^{10}}{cm^2\ s}\left(\frac{100\,cm}{1\,m}\right)^2 10^{-47}\,m^2 (.26)^2\ \frac{2700\,kg}{1.66\times10^{-27}}$$

$$= 7\times10^{-4}\ 1/s$$

$$= 20{,}000\ 1/year$$

Doping Ga·As



in conduction band

$$\frac{1}{m_*} = \frac{1}{\hbar^2}\frac{d^2 E(k)}{dk^2}$$

$$m_* = 0.07m$$

$$a_* = \frac{\hbar \epsilon_r}{\alpha m_* c} \approx 10\,nm$$

$$\epsilon = \epsilon_0 \epsilon_r$$
$$\epsilon_r = 13.2$$

$$\Delta E = -\frac{\alpha^2 m c^2}{2}\frac{m_*}{m}\frac{1}{\epsilon_r^2} = -13.6\,eV \frac{0.07}{(13.2)^2}$$

$$= -5.5\,meV$$

room temp. $k_B T = 8.6 \times 10^{-5}\,eV\ 300K$

$$\approx 25\,meV$$

replace N Ga with Si

density $n = \frac{N}{V}$

free electron more likely to be near positively charged ion

$$E(k,r) \approx \frac{\hbar^2 k^2}{2m_*} - e\phi(r)$$