

QM 115B Lec 26

Nuclear Scattering

$$V(r) = \beta \frac{e^{-\mu r}}{r}$$

$$\beta \approx \# \hbar c \quad \hbar c \sim [E L]$$

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

$$\mu = \frac{m_{\pi} c^2}{\hbar c}$$

$$\frac{135 \text{ MeV}}{6.58 \times 10^{-16} \text{ eVs}} \frac{1}{3 \times 10^8 \text{ m/s}} = 1.4 \times 10^{15} \text{ m}^{-1}$$

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

$$\approx 16\pi \text{ m}^2 (\hbar c)^2$$

$$\hbar^4 \mu^4 \left(\frac{m_{\pi} c}{\hbar} \right)^4$$

$$= 5.7 \times 10^{-27} \text{ m}^2$$

$$57 \text{ barns}$$

$$\frac{16\pi (980 \text{ MeV})^2 \hbar^2 c^2}{(135 \text{ MeV})^4}$$

Neutrino Elastic Scattering

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

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

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

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

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

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

low energy

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

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

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

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

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

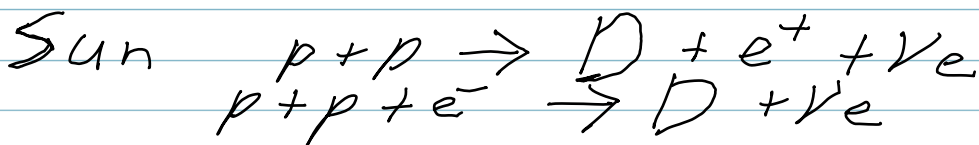
Mean Free Path in Lead

$$L = \frac{1}{n \cdot \sigma} = \frac{1}{\left(\frac{11400 \text{ kg}}{\text{m}^3} \frac{1}{1.66 \times 10^{-27} \text{ kg}} \right) 10^{-4} \text{ m}^2}$$

$$= 1.5 \times 10^{16} \text{ m} = 1.6 \text{ light years}$$

$$\text{Water } L = \frac{1}{n \cdot \sigma} = \frac{1}{\left(\frac{1000 \text{ kg}}{\text{m}^3} \frac{1}{1.66 \times 10^{-27} \text{ kg}} \right) 10^{-47} \text{ m}^2}$$

$$= 1.7 \times 10^{17} \text{ m} \approx 18 \text{ light years}$$



on Earth $L = \frac{6 \times 10^{10} \nu}{\text{cm}^2 \text{ s}}$

for 3 tons of water

$$E_{\text{ave}} = 0.26 \text{ MeV}$$

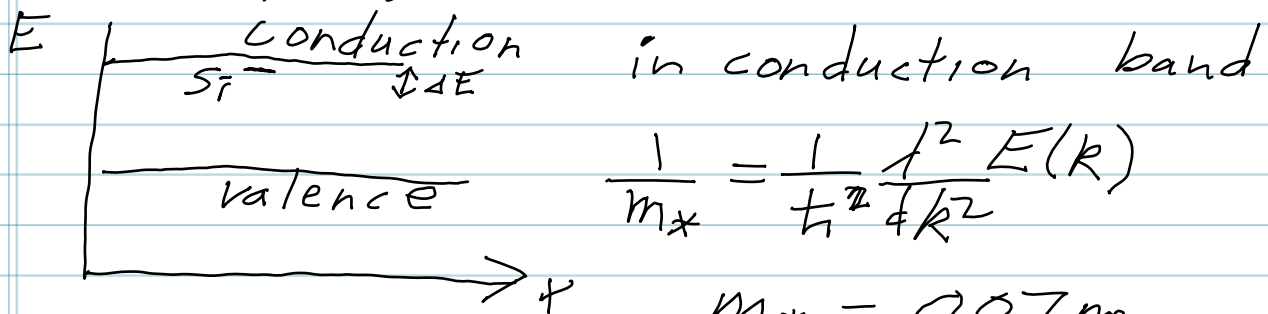
$$\text{Rate} = L \cdot \sigma \cdot n_{\text{targets}} \text{ s}$$

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

$$= 7 \times 10^{-4} \text{ 1/s}$$

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

Doping Ga-As



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

$$m^* = 0.07m$$

$$a_x = \frac{\hbar \epsilon_r}{\alpha m^* c} \approx 10 \text{ nm}$$

$$E = E_0 \epsilon_r$$

$$\epsilon_r = 13.2$$

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

$$= -5.5 \text{ meV}$$

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

$$\approx 25 \text{ meV}$$

replace N Ga with Si

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

free electron more likely to be near positively charged ion

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