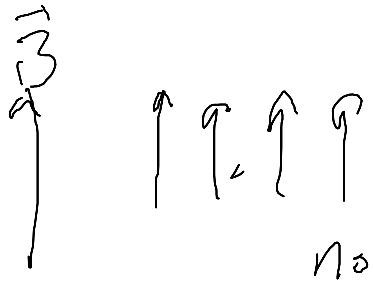
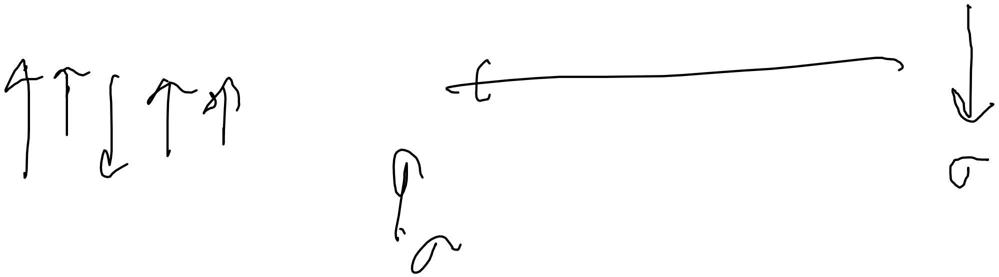
$\vec{\mu} = \gamma \vec{I}$



$\uparrow \vec{\sigma} \quad |+\rangle$

no interact. $\leftarrow$ n

$|-\rangle \quad \uparrow \mu$



$\Delta E = \pm(\mu_I B + \mu_n B)$

deuterium

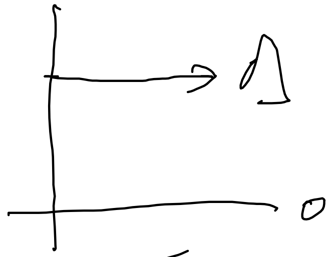
$\Delta E \sim 5\,\text{neV}$

30 T

$\mu_n = 6 \times 10^{-12}\,\text{eV/G}$

$= 6 \times 10^{-8}\,\text{eV/T}$

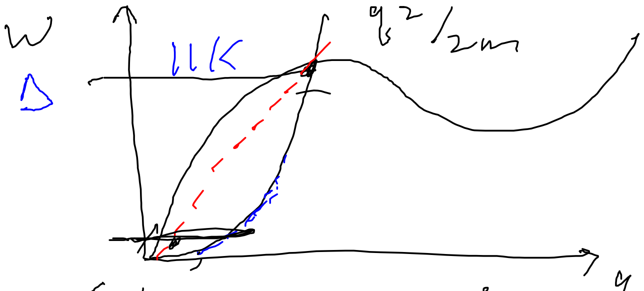
$\times 2$



$\Delta E_n = .12\,\mu\text{eV/T} \quad n$

$\rightarrow .18\,\mu\text{eV/T}$

$(n + d)$



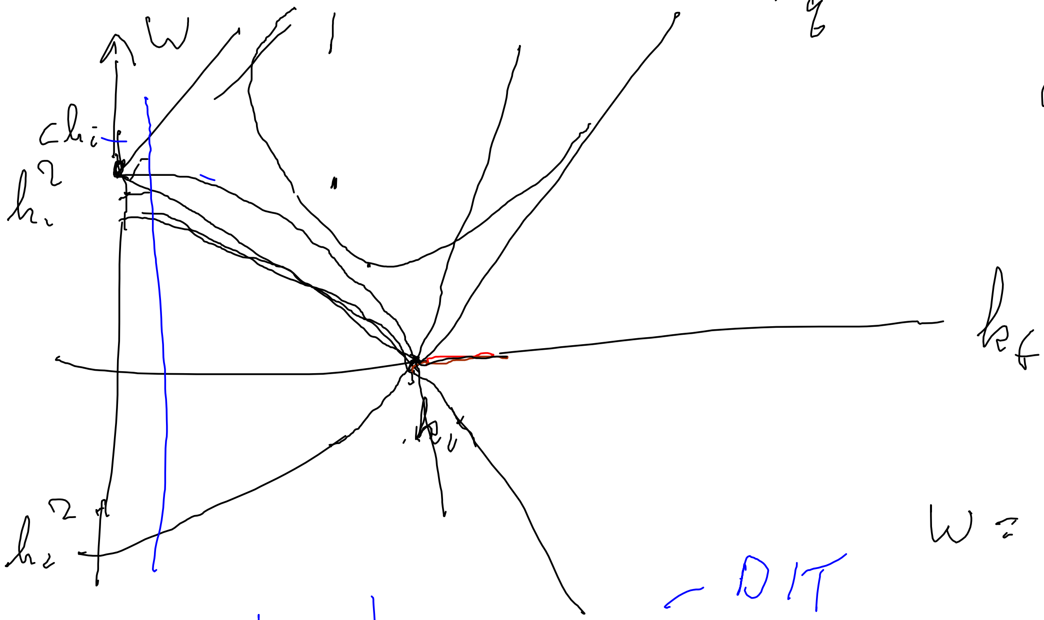
$\Gamma_{inc} = 0$

$V_m \ll V_w$

$V_{He} \sim 10^{-8}\,eV$

$2\times 10^{-7}\,eV$

$\Gamma_{abs} = 0$



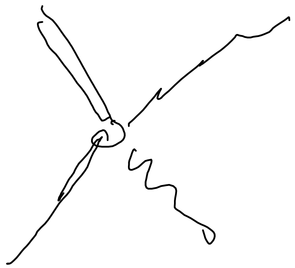
$\omega = k_f^2 - k_i^2$

$\omega = cq$

$|k_i - k_f| < q < |k_i + k_f|$

$\frac{1}{\tau_{wp}}\Big|_{ipwr} \sim e^{-\Delta/T}$

$T \sim .5K$



$\sim T^7$

$$P = \int \phi(E_0^*) \sum (E_0^* \to E_{vcm})\, dE_0\, dE_{vcm}$$

$$E^* e^{-E^*/T} \sum (E^* \to E_{vcm}) = E_{vcm} e^{-E_v/T} \sum (E_{vcm} \to E^*)$$

$$\sum (E_u \to E^*) = N \frac{\sigma_{coh}}{4\pi} \int \frac{k^*}{k_{vcm}} S(Q, \omega)\, d\Omega$$

$$\frac{d\sigma}{d\omega}$$

$Q = k^*$ $\quad \omega = E^*$

$$d\Omega = 2\pi \sin\theta\, d\theta$$

$$Q^2 = k^{*2} + k_u^2 - 2k^* k_u \cos\theta$$

$$(2Q\,dQ) = 2k^* k_u \sin\theta\, d\theta$$

$$2\pi \frac{Q\,dQ}{k^* k_u} = d\Omega$$

$$\frac{N\sigma_c}{2k_u^2} \iint \frac{1}{\cdot} S(Q,\omega)\, Q\, dQ$$

$$S(Q,\omega) = S(Q) \frac{\left[\dfrac{\delta(\omega - \omega_0(Q))}{e^{-\hbar\omega/2T}} + \dfrac{\delta(\omega + \omega_0(Q))}{e^{\hbar\omega/2T}} \right]}{e^{-\hbar\omega_0/2T} + e^{\hbar\omega_0/2T}}$$

$\omega_0/T \gg 1$

$$= \left[S(Q)\, \delta(\omega - \omega_0(Q))\, e^{-\hbar\omega_0/T} \right]$$

$$\delta\left\{ \omega - \omega_0(Q_1) - [v_n - \omega'(Q)](Q - Q') \right\} \quad \omega = \omega_0(Q_1)$$

$$\delta(\omega_0'(Q_1)(Q - Q_1)) = \frac{1}{\omega_0'(Q_1)} \delta(Q - Q')$$

$$\frac{d\omega_0}{dQ} = v_g$$

$$\int \frac{N\sigma_c}{2k_{u}^2} \frac{1}{\omega_0'(Q)} Q^* S(Q) e^{-E^*/T}\, d\omega$$

$$\omega = \frac{k^{*2}}{2m} \qquad d\omega = \frac{k^*}{m} dk^* = v_n\, dk^*$$

$$\frac{v_n}{v_n - v_g}$$

$$\int dE_1\, \varsigma(E_1 \to E_u) = \int dE_1\, \frac{E_u}{E_1} e^{E_1/T}\, \sigma(E_u \to E_1)$$

$$= \int \sigma_{coh} \frac{k_u}{k^*}\, \alpha\, S(k^*)$$

$$\alpha = \frac{v_u}{|v_u - v_g|}$$

$$\omega = c k^* = \frac{\hbar k^{*2}}{2m}$$

$\alpha = 2$ linear dispersion

$$k^* = \left(\frac{2mc}{\hbar}\right)$$

$\varphi = 1.45$

$$v_u = \frac{\hbar k^*}{m} = 2c$$

$$P(E_{ucn})\, dE_{ucn} = N \phi(E^*)\, \sigma_{coh} \sqrt{\frac{E_u}{E^*}}\, \alpha S(k^*)$$

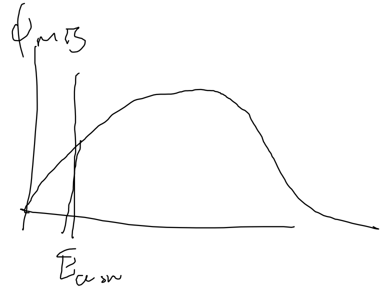
$$\int_0^{E_1} P\, dE_{ucn} = \phi(E^*) \times 10^{-7} \text{ UCN/cm}^3\text{/sec}$$

$$\phi(E^*) = \left(\frac{E^*}{T^2} e^{-E^*/T}\right) \phi_0$$

$T = 300\,K$

$$P(E_{ucn}) = 1.3 \times 10^{-11} \phi_{th}$$

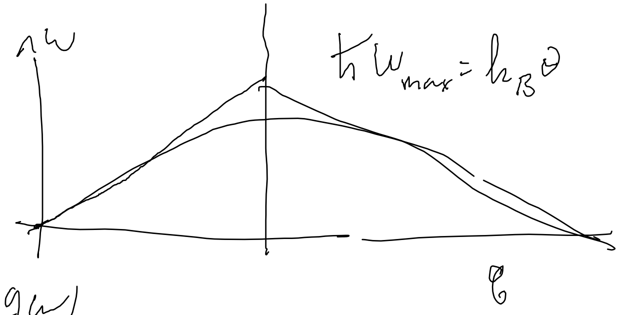
$$\rho_{ucn} = 1.3 \times 10^{-11} \phi_{th}\, \tau$$



$$\rho^{MB}_{ucn} = 10^{-13} \phi_{th}$$

Deuterium   incoherent approximation

$$\frac{d^2\sigma}{d\Omega\, d\omega} = a^2 \frac{k_n}{k_1} e^{-\gamma q^2} \frac{\hbar}{2M} \frac{g(\omega)\, q^2}{\omega\left(1 - e^{-\omega/T}\right)}$$



$$\hbar \omega_{max} = k_B \theta$$

$$g(\omega) = \frac{3\omega^2}{\left(k_B\theta/\hbar\right)^3}$$

$$\int_0^\theta g(\omega)\, d\omega = 1$$

$$g(\omega) = \qquad \omega < \theta$$

$$= 0 \qquad \omega > \theta$$

$$\phi(E_1) = \phi_{MB}(E_0) = \frac{E_0}{T_n} e^{-E_0/T_n} \phi_0$$

$$P = \phi_0 \frac{4\pi}{T_n^2} \frac{3}{(k_B\theta)^3} \frac{m_n}{M} (E_\omega)^{1/2} \int_0^\theta E_0^{5/2} e^{-\beta E_0}\, dE_0$$

$$\beta = \left(\frac{\gamma\, 2m}{\hbar^2} + \frac{1}{T_n}\right)$$


10 meV
q


g(ω)
Θ ~ 110 K