5/30/03

Some follow-ups to the quasi-elastic electron scattering discussion...

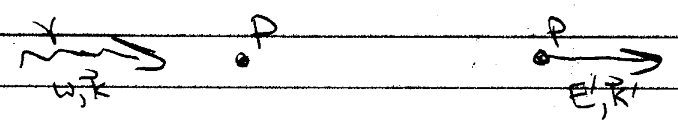
Let's review the basic physics behind the quasi-elastic scattering process. Start with a <u>real</u> photon with wave number $|\vec{k}| = 2\pi/\lambda$.

- real photon $\Rightarrow \omega = |\vec{k}|$

  [remember $\hbar = c = 1$, so this really says $\hbar\omega = \hbar k c$]

- can this be absorbed by a stationary proton?

before   after?



energy conservation $\boxed{\omega = E' = k'^2/2m}$ (if non-relativistic)

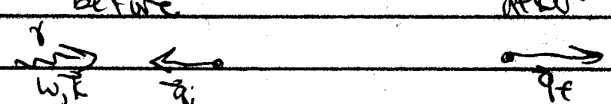
momentum " $\boxed{\vec{k} = \vec{k}'}$

$\Rightarrow \omega = k \quad \Rightarrow \omega = k^2/2m = k\left(\frac{k}{2m}\right)$ which doesn't work for $k < 2m$

- <u>But</u>, if we have a virtual spacelike photon ($\omega < k$), then we can satisfy energy and momentum conservation for a stationary proton with fixed k (adjust ω until $\omega = k^2/2m$).
  - So what is the least ω that can be absorbed at fixed $\vec{k}$?

    $\Rightarrow$ let the proton be moving $\rightarrow$ at most $|\vec{q}_i| = k_f$ toward the photon if we have a free Fermi gas.

before   after



energy: $\omega_{min} + \frac{k_f^2}{2m} = \frac{q_f^2}{2m}$ momentum $|\vec{k} - |\vec{q}_i|| = k - k_f = |\vec{q}_f| \equiv q_f$

$\Rightarrow \omega_{min} + \frac{k_f^2}{2m} = (k-k_f)^2/2m$ or $\omega_{min} = \frac{k^2}{2m} - \frac{k k_f}{m}$

- similarly, $\omega_{max} = \frac{k^2}{2m} + \frac{k k_f}{m}$

What if the target (say a nucleus) had constituents that felt some average potential $-\bar{V}$ ($\bar{V} > 0$).

- If it is the same for bound and free constituents, then it just adds to either side of the energy conservation equation and nothing changes.
- But if the potential for bound constituents is $-\bar{V}$ while for the highly excited knocked out particle is roughly 0, then the quasi elastic response function for $k > 2k_F$ is shifted by $\bar{V}$. Or, if the potential is still attractive for the knocked out particle, we can estimate the shift by the average binding energy $\bar{\epsilon}$ of bound constituents.
- The other way is to use $m \to m^*$ so the peak shifts to $k^2/2m^*$.

- Let's look at another picture from Negele and Orland (Fig. 5.17), which is a contour plot in the (q,ω) plane of the cross section for inelastic scattering of neutrons from liquid ^3He at $0.63°K$.
  - On the scale of Å's relevant to this experiment, the neutron-^3He potential is effectively a delta function

$$\Rightarrow \quad \sigma \propto \operatorname{Im} D(q,\omega)$$

  - The ground state density implies $k_F = 0.786\,\text{Å}^{-1}$.
  - The maximum $q^2/2m$ and zeros $q^2/2m \pm q k_F/m$ from $D_0(q,\omega)$ are indicated by dashed lines.

- Does it look like D_0?
  - Look at the $q \sim 2k_F$ region: where is the peak?
    - What does this imply about m^*?

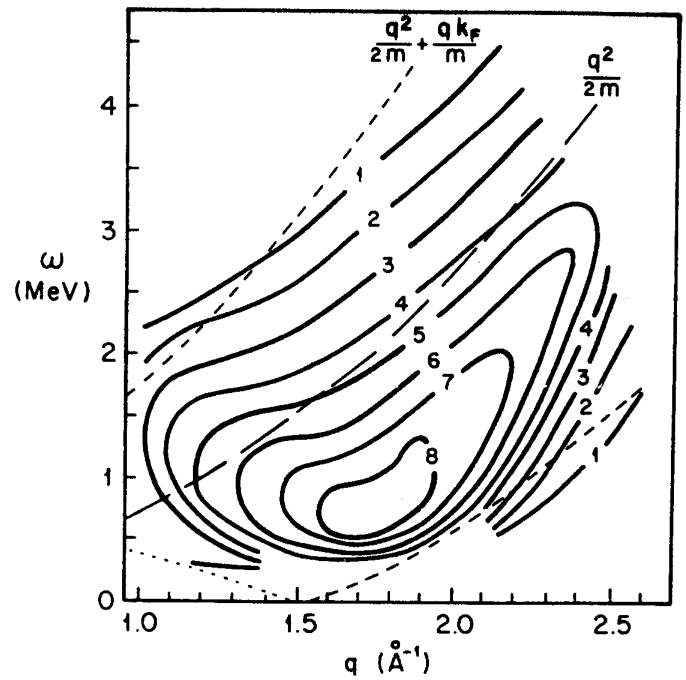


Fig. 5.17 Sketch of cross section for inelastic neutron scattering from liquid ^{3}He based on the data of Stirling *et al* (1976). Solid contours denote the experimental cross sections, the long dashed curve indicates the Fermi gas maximum, $\frac{q^2}{2m}$, the short dashed curves show where the Fermi gas response goes to zero, $\frac{q^2}{2m} \pm \frac{qk_F}{m}$, and the dotted line denotes the point at which Pauli blocking begins.