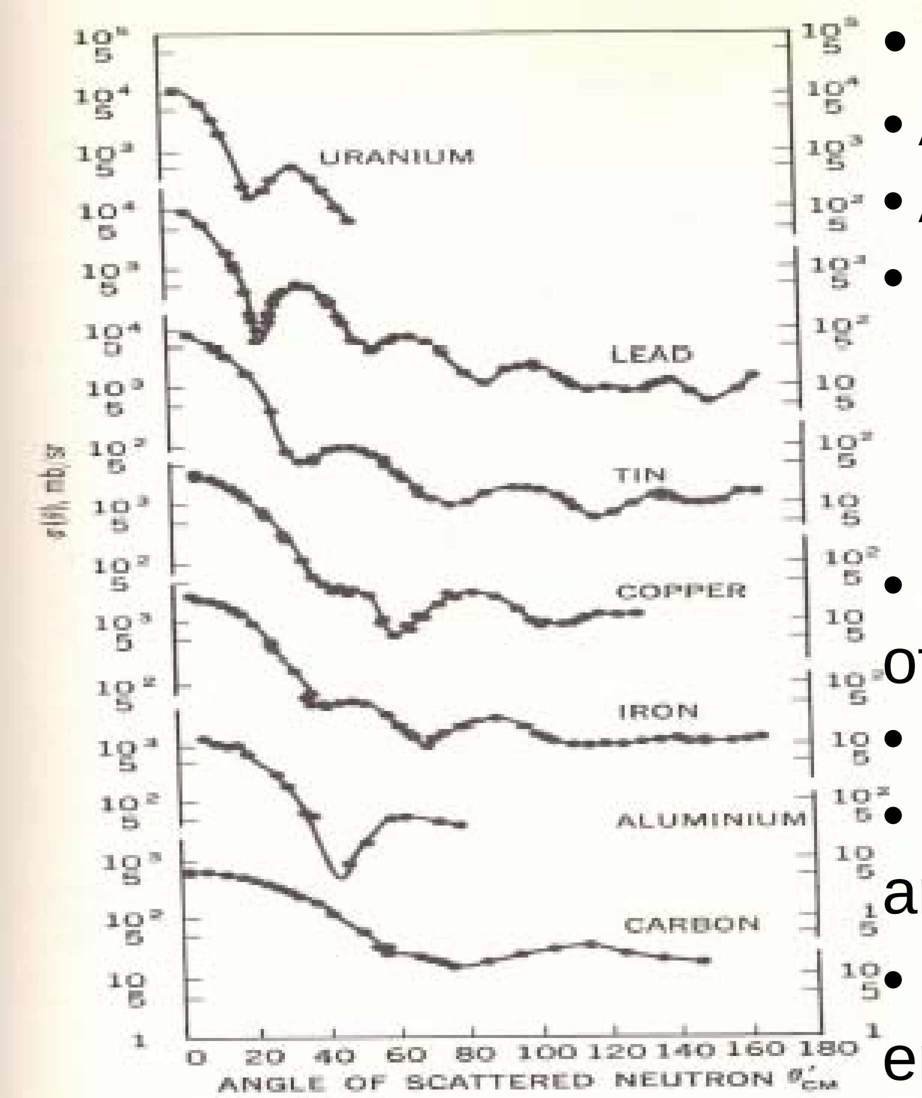
Nuclear Scattering



- Elastic or inelastic.
- Analogous to diffraction.
- Alternating maxima and minima.
- First maximum at $\theta \approx \frac{\lambda}{R}$

$$\lambda = \frac{h}{p}$$

$$R = R_o A^{1/3}$$

- Minimum not at zero (sharp edge of the nucleus??)
- Clear for neutrons.
- Protons? High energy, large angles. Why?
- Inelastic ▶ Excited states, energy, X-section and spin-parity.

Reaction Cross Section(s)

- Probability.
- Projectile *a* will more probably hit target *X* if area is larger.
- Classically: $\sigma = \pi(R_a + R_X)^2$.

Classical σ = ??? (in b) $^{1}H + {}^{1}H$, $^{1}H + {}^{238}U$, $^{238}U + {}^{238}U$

- Quantum mechanically: $\sigma = \pi\, ƛ^2$.

HW 14

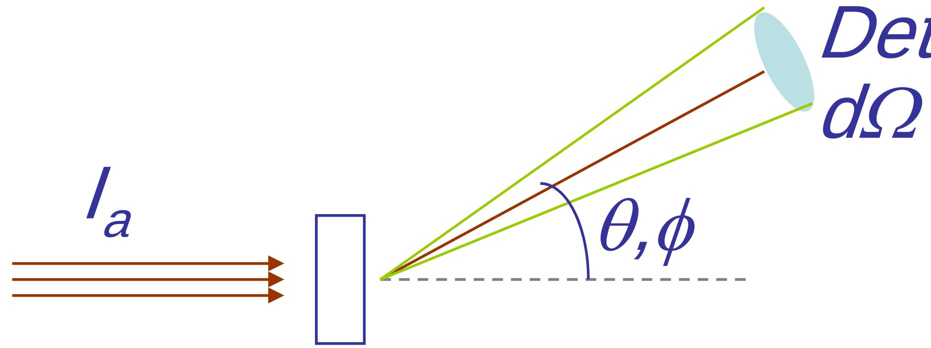
$$ƛ = \frac{m_a + m_X}{m_X}\frac{\hbar}{\sqrt{2m_aE_a}} = \frac{\hbar}{\sqrt{2\mu_{aX}E_{aX}^{CM}}}$$

- Coulomb and centrifugal barriers ▶ energy dependence of σ.
- Nature of force:

Strong:	$^{15}N(p,\alpha)^{12}C$	σ = 0.5 b at E_p = 2 MeV.
Electromagnetic:	$^{3}He(\alpha,\gamma)^{7}Be$	$\sigma = 10^{-6}$ b at E_α = 2 MeV.
Weak:	$p(p,e^{+}\nu)D$	$\sigma = 10^{-20}$ b at E_p = 2 MeV.

- Experimental challenges to measure low X-sections..

Reaction Cross Section(s) (Introduction)



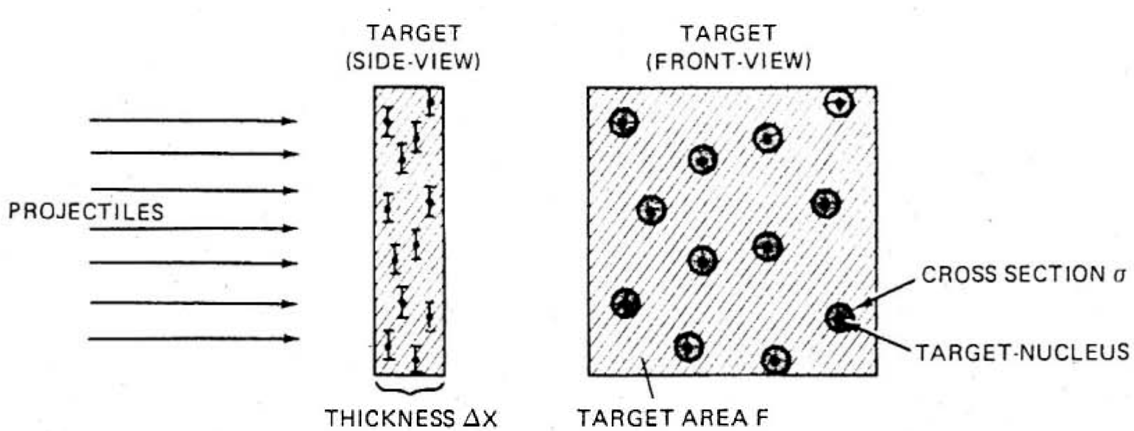
"b" particles / s

cm^2

$$d\sigma = \frac{dR_b}{I_a N}$$

"a" particles / s

"X" target Nuclei / cm^2



Typical nucleus (R=6 fm): geometrical $\pi R^2 \approx 1$ b.
Typical σ: <μb to >10^6 b.

Reaction Cross Section(s) (Introduction)

Many different quantities are called "cross section".

Krane Table 11.1

Units … !

"Differential" cross section

$\sigma(\theta,\phi)$ or $\sigma(\theta)$

or "cross section" …!!

Angular distribution

$$dR_b = r(\theta,\phi)\frac{d\Omega}{4\pi}$$

$$\frac{d\sigma}{d\Omega} = \frac{r(\theta,\phi)}{4\pi I_a N}$$

Spectroscopic Factor.

$$\left(\frac{d\sigma}{d\Omega}\right)_{meas} = S\left(\frac{d\sigma}{d\Omega}\right)_{calc}$$

$$d\Omega = \sin\theta d\theta d\phi$$

$$\sigma = \int \frac{d\sigma}{d\Omega} d\Omega = \int_0^{\pi} \sin\theta d\theta \int_0^{2\pi} d\phi \frac{d\sigma}{d\Omega}$$

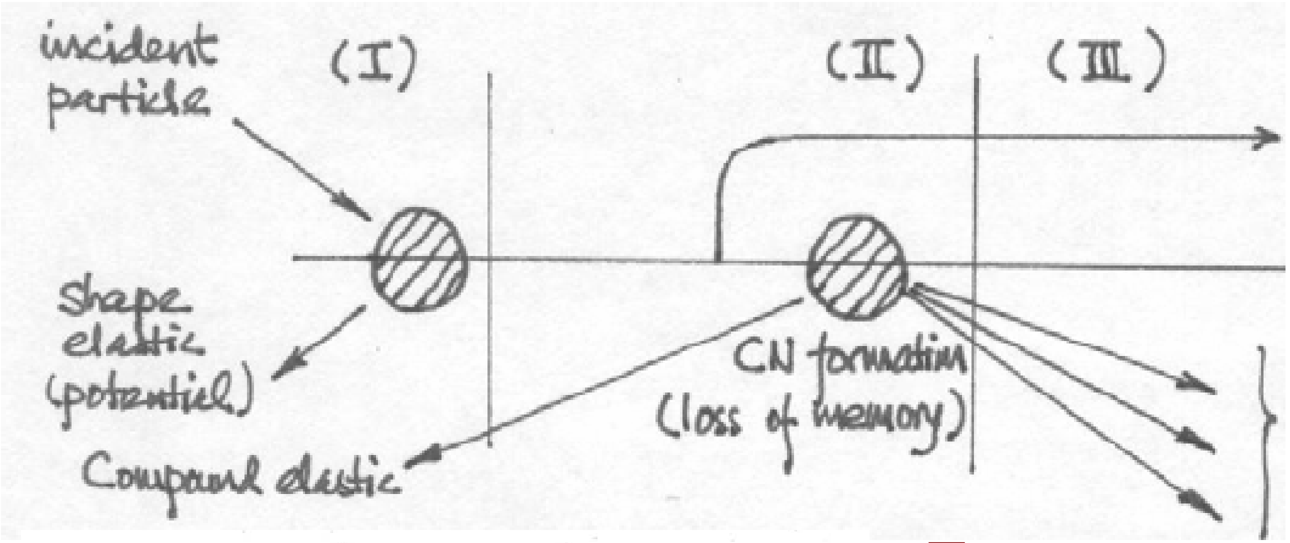
σ_t for all "b" particles.

Doubly differential

$$\frac{d\sigma}{dE} \qquad \frac{d^2\sigma}{dE_b d\Omega}$$

Energy state in "Y"

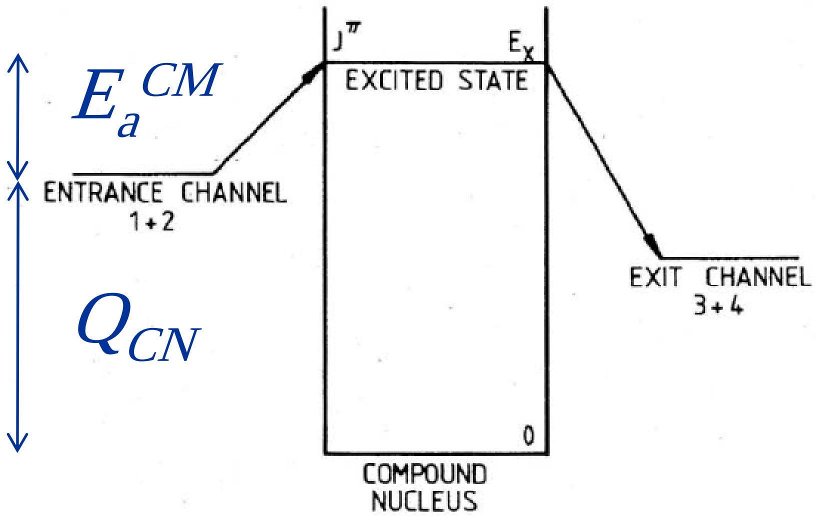
Compound Nucleus Reactions



Direct

- Time.
- Energy.

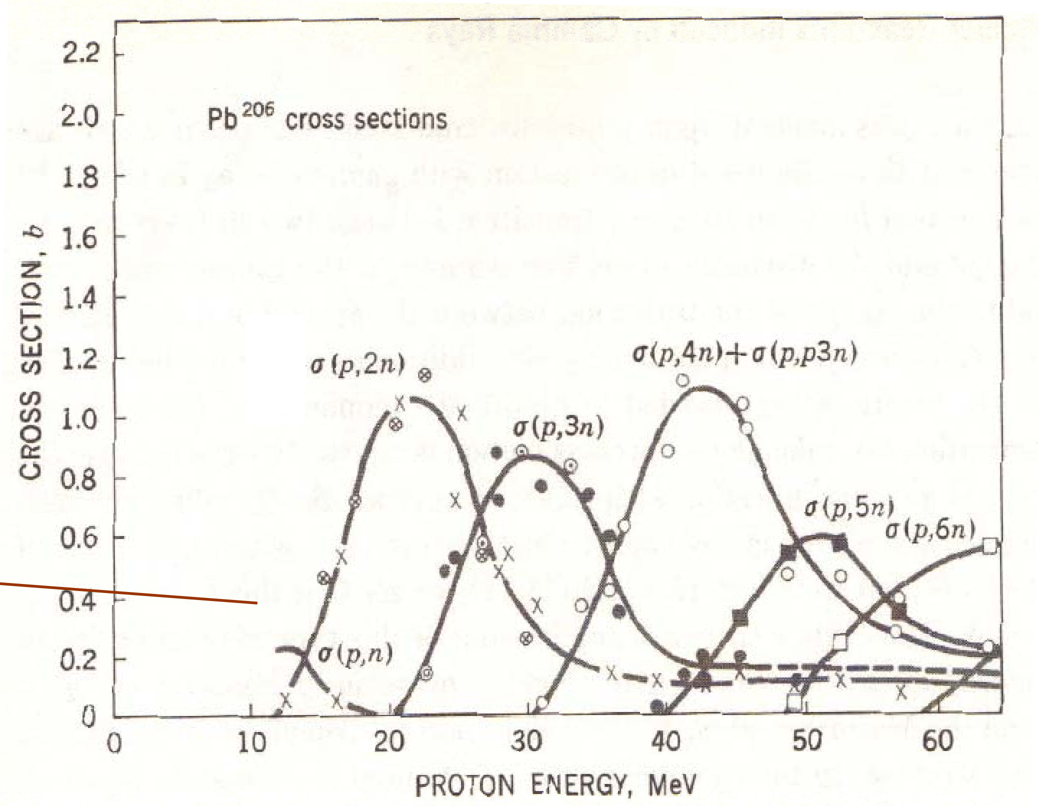
CN decays



- Two-step reaction.
- CN “forgets” how it was formed.
- Decay of CN depends on statistical factors that are functions of E_x, J.
- Low energy projectile, medium or heavy target.

Compound Nucleus Reactions

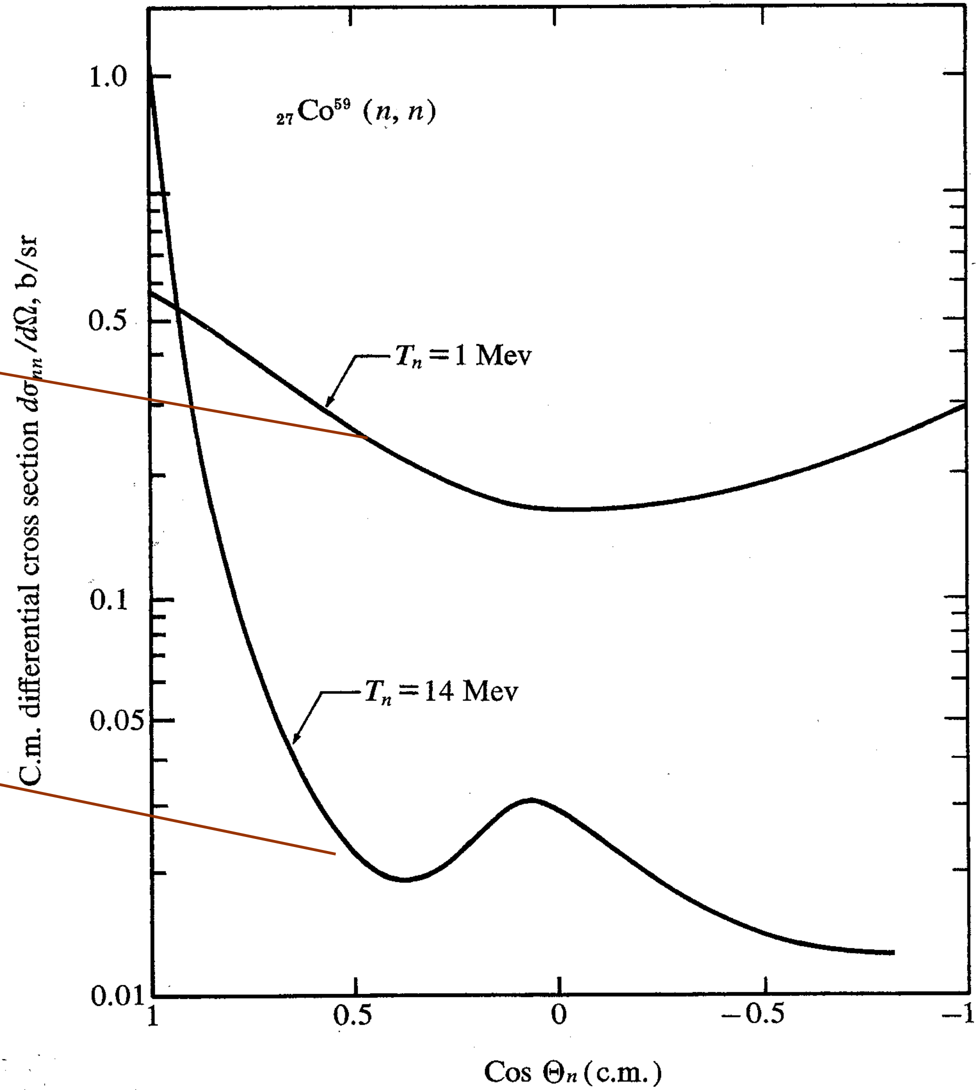
- Consider $p + {}^{63}Cu$ at E_p^{CM}= 20 MeV.
- Calculate $E_p^{CM} + [m({}^{63}Cu) + m(p) - m({}^{64}Zn)]c^2$.
- Divide by 64 ▶ available energy per nucleon << 8 MeV.
- Multiple collisions ▶ "long" time ▶ statistical distribution of energy ▶ small chance for a nucleon to get enough energy ▶ Evaporation.
- Higher incident energy ▶ more particles "evaporate".



See also Fig. 11.21 in Krane.

Direct Reactions

- Random collisions ▶ nearly isotropic angular distribution.
- Direct reaction component ▶ strong angular dependence.



See also Fig. 11.20 in Krane.