

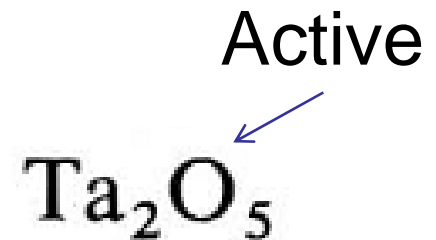
Target Properties and Reaction Yield

- *Thin target Yield* = $\sigma n_a \Delta X = \sigma \Delta / \epsilon$ for “pure active” target.
- If the target contains active and inactive (inert) nuclei:

$$Y = \sigma \frac{\Delta_{\text{eff}}}{\epsilon_{\text{eff}}}$$

$$\Delta_{\text{eff}} = N_a \epsilon_a + \sum_i N_i \epsilon_i$$

$$\epsilon_{\text{eff}} = \epsilon_a + \frac{1}{N_a} \sum_i N_i \epsilon_i = \frac{\Delta_{\text{eff}}}{N_a}$$



$$\epsilon_{\text{eff}} = \epsilon_{\text{O}} + \frac{2}{5} \epsilon_{\text{Ta}}$$

$$N_a = n_a \Delta X = \frac{v_a \rho N_A \Delta X}{A} = v_a N_{\text{molecules}}$$

$$N_i = v_i N_{\text{molecules}}$$

$$\epsilon = \frac{N_a}{N_{\text{molecules}}} \epsilon_a + \sum_i \frac{N_i}{N_{\text{molecules}}} \epsilon_i$$

$$\epsilon_{\text{eff}} = \epsilon \frac{N_{\text{molecules}}}{N_a} = \frac{\Delta_{\text{eff}}}{N_a}$$

Target Properties and Reaction Yield

- Caution when prepare targets by evaporation or sputtering.

<http://www.mems-exchange.org/MEMS/processes/deposition.html>

http://www.heraeus-targets.com/en/technology/_sputteringbasics/sputtering.aspx

- Stoichiometry could change.

http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=5081898

- **NRA. Depth profile. PIGE.**

- For a finite target thickness:

$$Y(E_0) = \int \sigma(E)ndx = \int_{E_0 - \Delta}^{E_0} \frac{\sigma(E)}{\epsilon(E)} dE$$

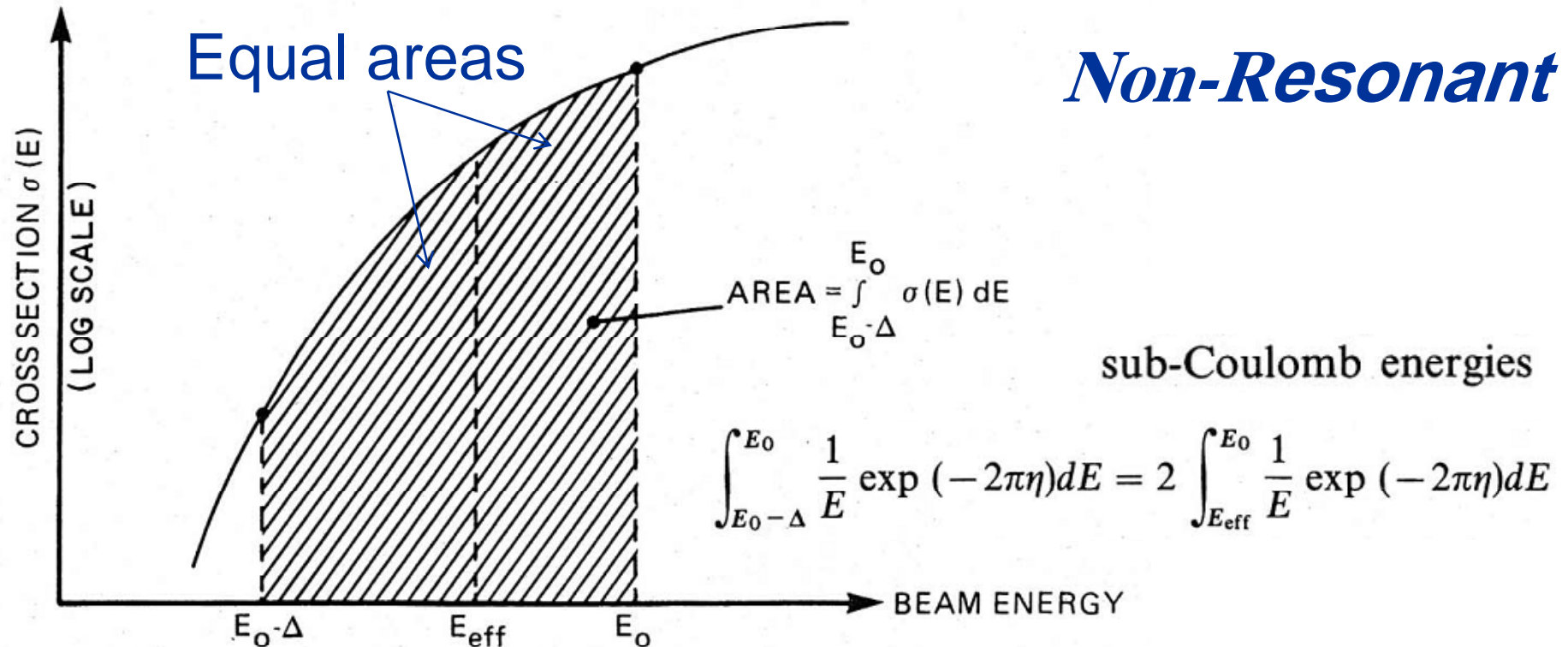
Incident energy

- What if the target is “infinitely” thick?

$$Y(E_0) = \int \sigma(E)ndx = \int_0^{E_0} \frac{\sigma(E)}{\epsilon(E)} dE$$

Target Properties and Reaction Yield

- For a thin target:
$$Y(E_0) = \frac{1}{\epsilon(E_0)} \int_{E_0 - \Delta}^{E_0} \sigma(E) dE = \frac{2}{\epsilon(E_0)} \int_{E_{\text{eff}}}^{E_0} \sigma(E) dE$$

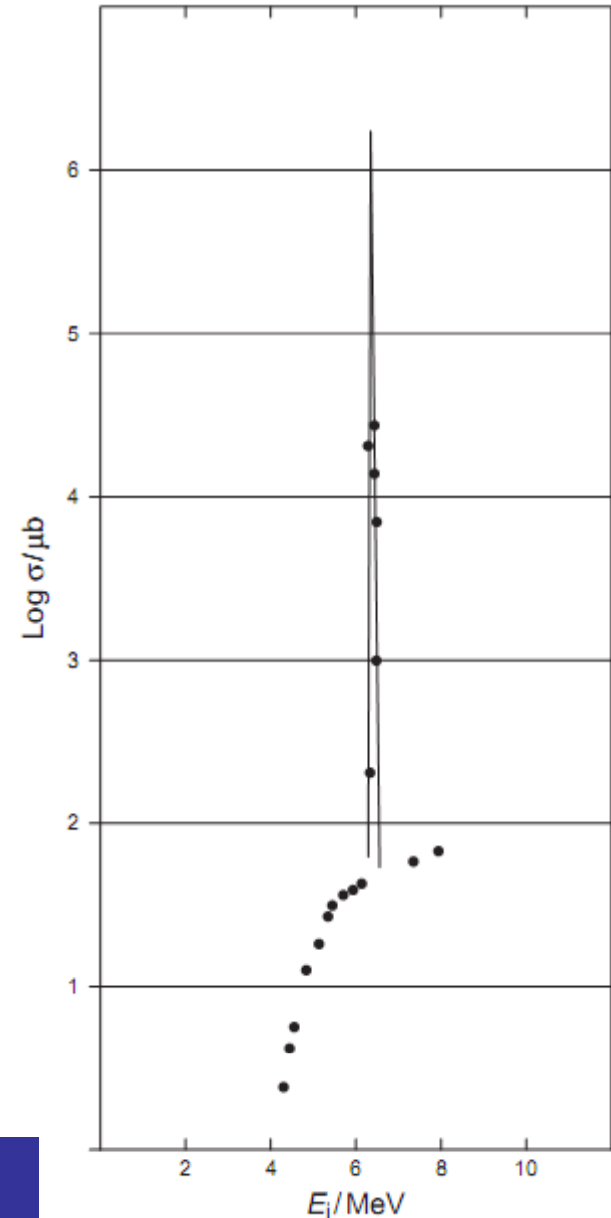
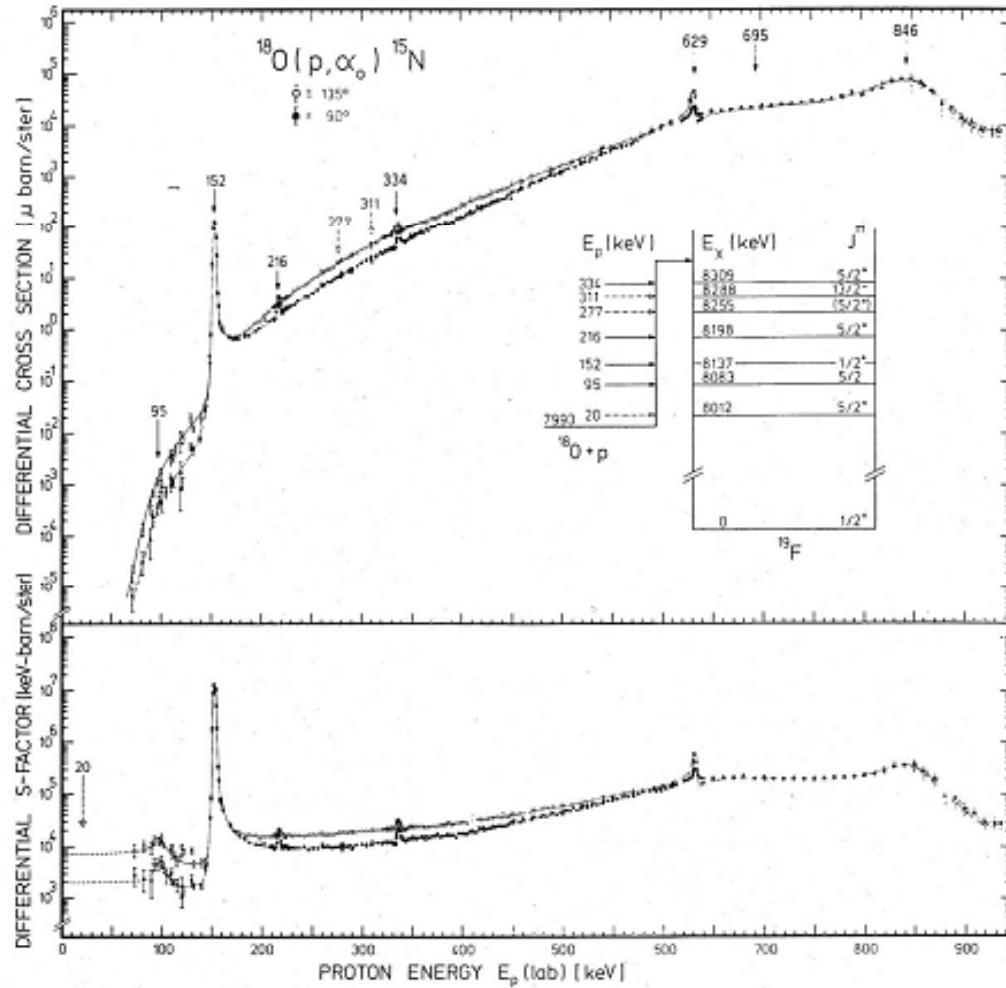


- If also the cross section is energy independent (at higher energies):

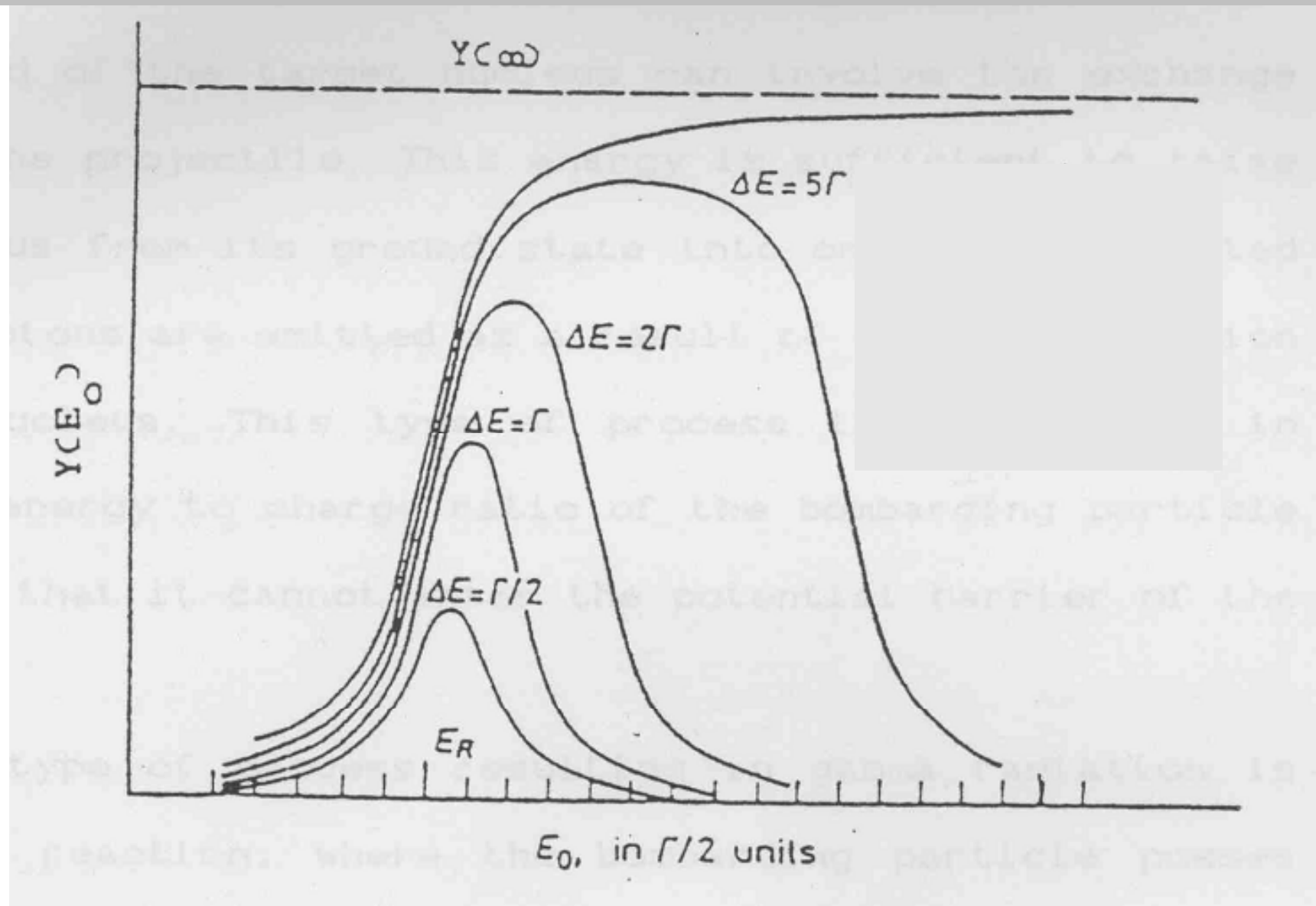
$$\sigma(E_{\text{eff}}) = Y(E_0)\epsilon(E_0)/\Delta \quad E_{\text{eff}} = E_0 - \Delta/2$$

Target Properties and Reaction Yield

Resonances



Target Properties and Reaction Yield



Target Properties and Reaction Yield

- *Narrow resonances* ($\Gamma \ll E_R$).

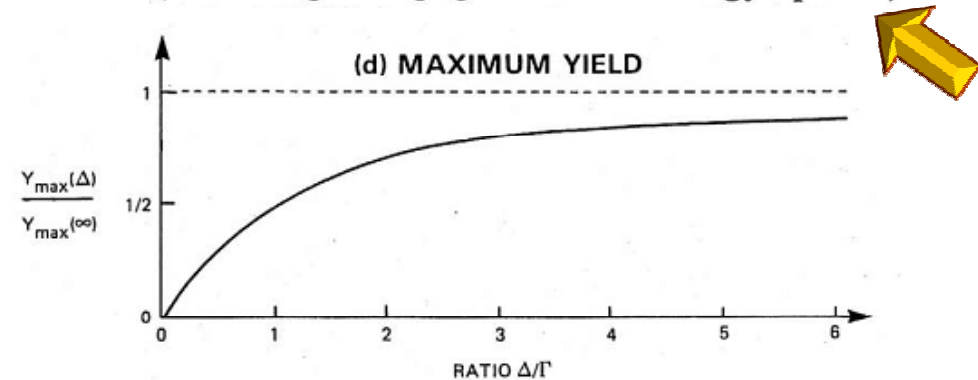
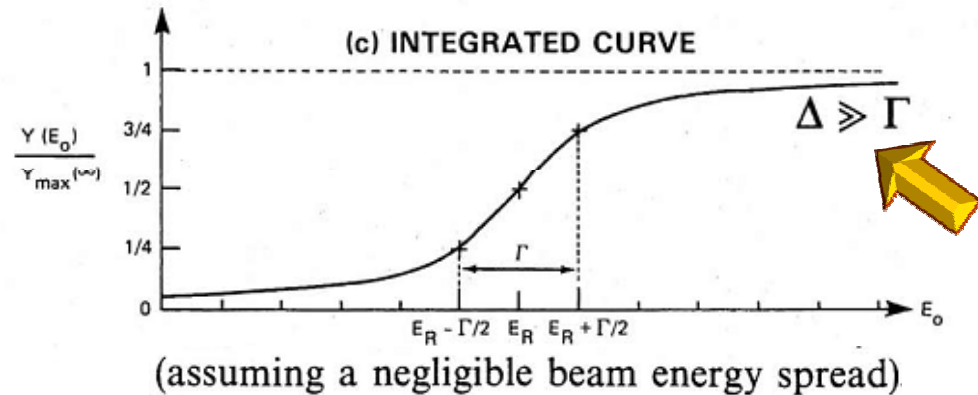
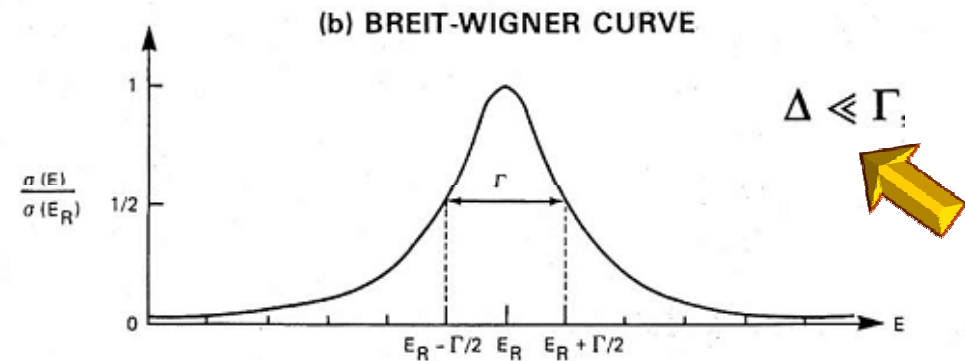
$$\sigma_{\text{BW}}(E, E_R) = \pi \lambda^2 \omega \frac{\Gamma_a \Gamma_b}{(E - E_R)^2 + (\Gamma/2)^2}$$

HW 12

$$Y(E_0) = \frac{\lambda^2}{2\pi} \omega \gamma \frac{M+m}{M} \frac{1}{\epsilon} \left[\arctan\left(\frac{E_0 - E_R}{\Gamma/2}\right) - \arctan\left(\frac{E_0 - E_R - \Delta}{\Gamma/2}\right) \right]$$

$$Y_{\text{max}}(\infty) = \frac{\lambda^2}{2} \omega \gamma \frac{M+m}{M} \frac{1}{\epsilon}$$

$$\frac{Y_{\text{max}}(\Delta)}{Y_{\text{max}}(\infty)} = \frac{2}{\pi} \arctan\left(\frac{\Delta}{\Gamma}\right)$$



Target Properties and Reaction Yield

$$Y = \sigma \frac{\Delta_{\text{eff}}}{\epsilon_{\text{eff}}} \qquad Y_{\text{max}}(\infty) = \frac{\lambda^2}{2} \omega \gamma \frac{M+m}{M} \frac{1}{\epsilon}$$



Both components

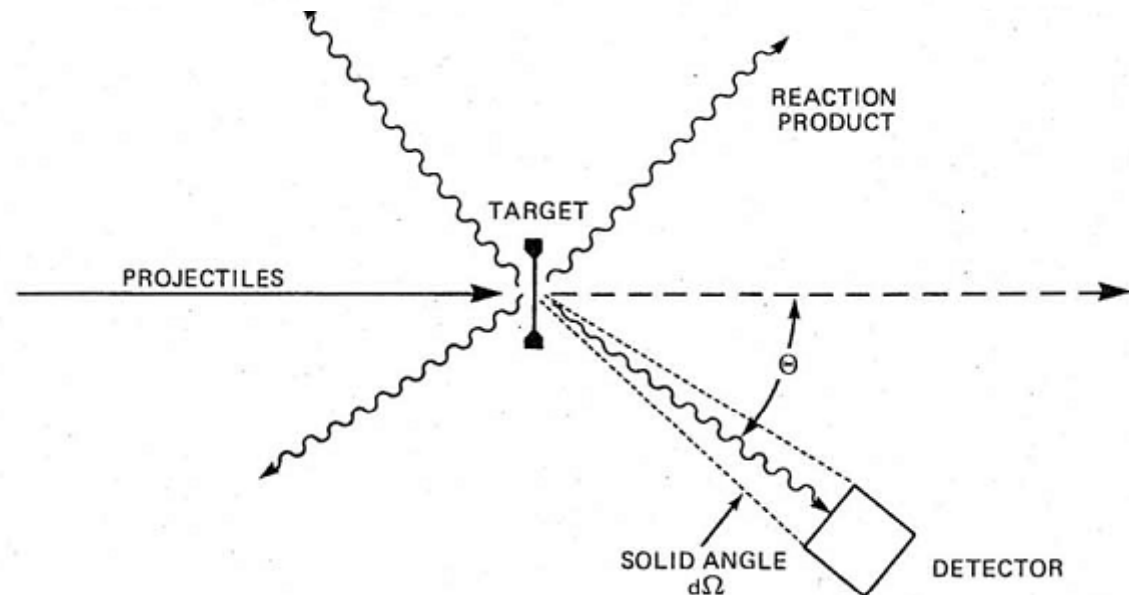
$$\frac{Y_r(\infty)}{Y_{\text{nr}}(E)} = \frac{\lambda^2(E_R)}{2} \frac{M+m}{M} \frac{\epsilon_{\text{lab}}(E)}{\epsilon_{\text{lab}}(E_R)} \frac{\omega \gamma(E_R)}{\sigma(W) \Delta_{\text{lab}}(E)}$$

$$E \cong E_R ?$$

Target Properties and Reaction Yield

In the above sections we have discussed the reaction yield per incident projectile for a nuclear reaction $A(x, y)B$. If N_p projectiles are impinging on the target over a time period t , the resulting yield is $N_p Y$, which is in general emitted in all directions. In an actual experiment a detector of finite solid angle $d\Omega$ is placed at a detection angle θ (Fig. 5.38a), and thus only a fraction of the yield $N_p Y$ is detected. Often the light reaction products y are detected and the number of events $N_y(\theta)$ registered in the detector over the time period t is given by the equation

$$N_y(\theta) = N_p Y \epsilon_y d\Omega_y W_y(\theta) I_\gamma$$



Target Properties and Reaction Yield

$$Y = \sigma \frac{\Delta_{\text{eff}}}{\epsilon_{\text{eff}}} \quad N_y(\theta) = N_p Y \epsilon_y d\Omega_y W_y(\theta)$$



$$\sigma(E) = \frac{N_y(E, \theta) \epsilon_{\text{lab}}(E)}{N_p(E) \epsilon_y(E) d\Omega_y(E) W_y(E, \theta) \Delta_{\text{lab}}(E)}$$

Thus, accurate information must be available on the angular distribution $W_y(E, \theta)$, the absolute number of projectiles $N_p(E)$, the detector properties $\epsilon_y(E) d\Omega_y(E)$, and the target features $\epsilon_{\text{lab}}(E)/\Delta_{\text{lab}}(E)$. Their determination is often quite time-consuming and frequently involves novel techniques.

Target Properties and Reaction Yield

Relative method

$$Y_{\max}(\infty) = \frac{\lambda^2}{2} \omega \gamma \frac{M + m}{M} \frac{1}{\epsilon} \quad N_y(\theta) = N_p Y \epsilon_y d\Omega_y W_y(\theta)$$

$$\frac{N_y(\theta)}{N_w(\theta)} = \frac{N_p(x)}{N_p(z)} \frac{\epsilon_y}{\epsilon_w} \frac{W_y(\theta)}{W_w(\theta)} \frac{\lambda_x^2}{\lambda_z^2} \frac{M_A + m_x}{M_A} \frac{M_C}{M_C + m_z} \frac{\epsilon_{\text{lab}}(A)}{\epsilon_{\text{lab}}(C)} \frac{\omega \gamma(y)}{\omega \gamma(w)}$$

A(x, y)B

C(z, w)D

Unknown

Standard



Same reaction, different resonances?