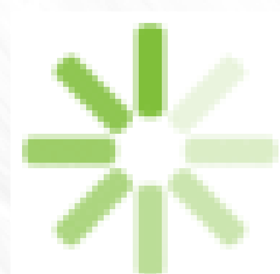
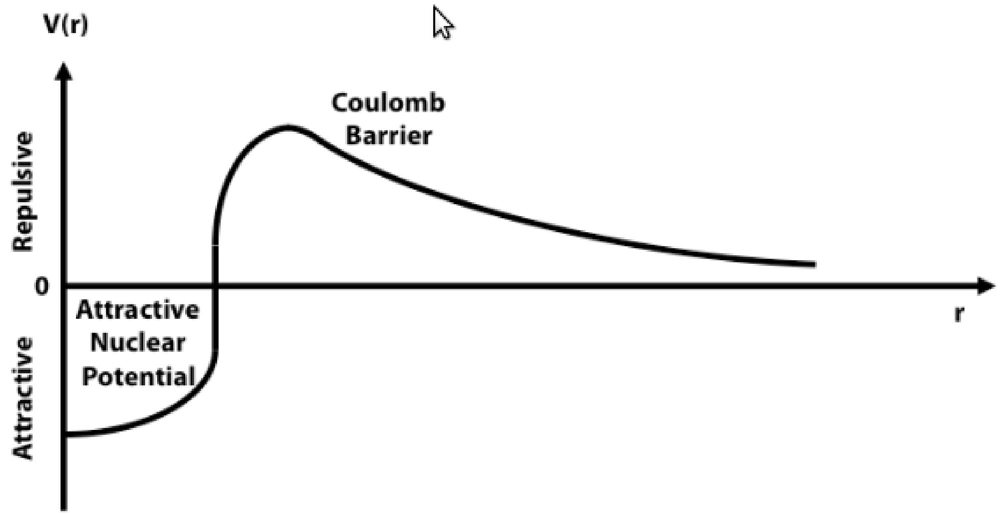


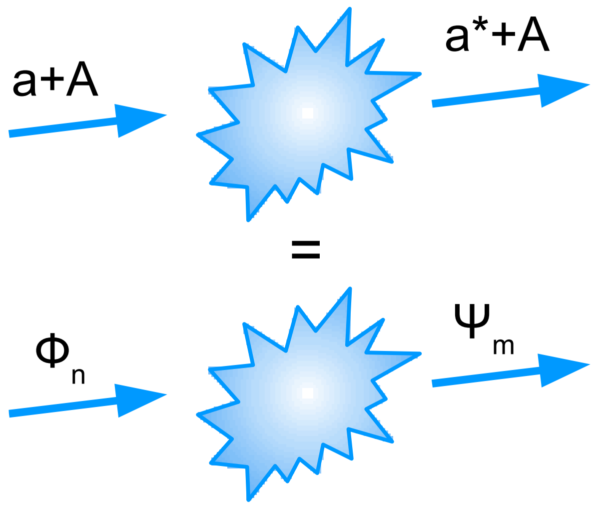
Nuclear reactions

A theoretical presentation

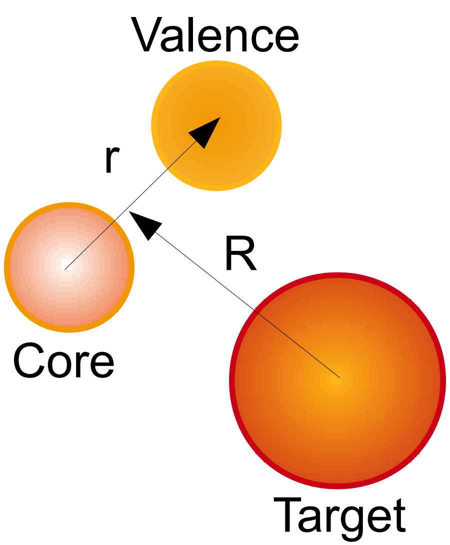
Potentials

A brief introduction





$$P_n = |\langle \Phi_n | \Psi_m \rangle|^2$$

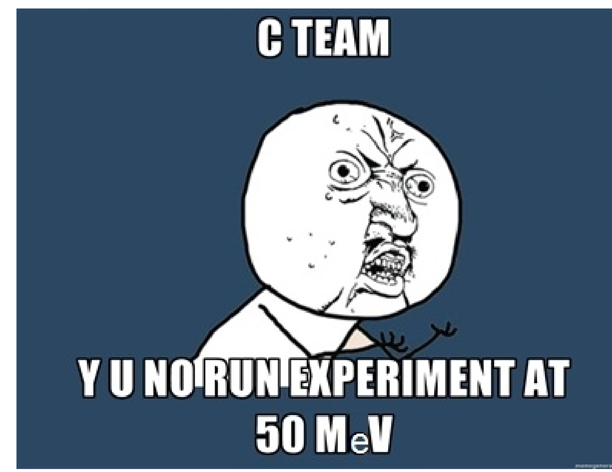


$$H(r,R)\,\psi(r,R) = E\,\psi(r,R)$$
$$H(r,R) = H_o(r) + T(R) + V(r,R)$$
$$\psi(r,R) = \varphi(r)\chi(R)$$

1. Optical model
2. Coupled channels
3. Distorted Wave Born Approximation (DWBA)

Case of our study

Main goals:
- Learning the basics about calculating nuclear reactions by using a computer
- Learning the basics of the reaction code FRESCO



CASE OF STUDY ► ^{20}Ne + ^{12}C @ 50 MeV

Goals:
- Running calculations for elastic and inelastic scattering and for transfer reactions
- Comparing our results with the experimental results from group C

Basic classification

Channels

$^{20}Ne+^{12}C$

Elastic scattering

$^{20}Ne+^{12}C$

Inelastic scattering

$^{20}Ne^{*}+^{12}C$

$^{20}Ne+^{12}C^{*}$

$^{20}Ne^{*}+^{12}C^{*}$

Reactions

$^{16}O+^{16}O$

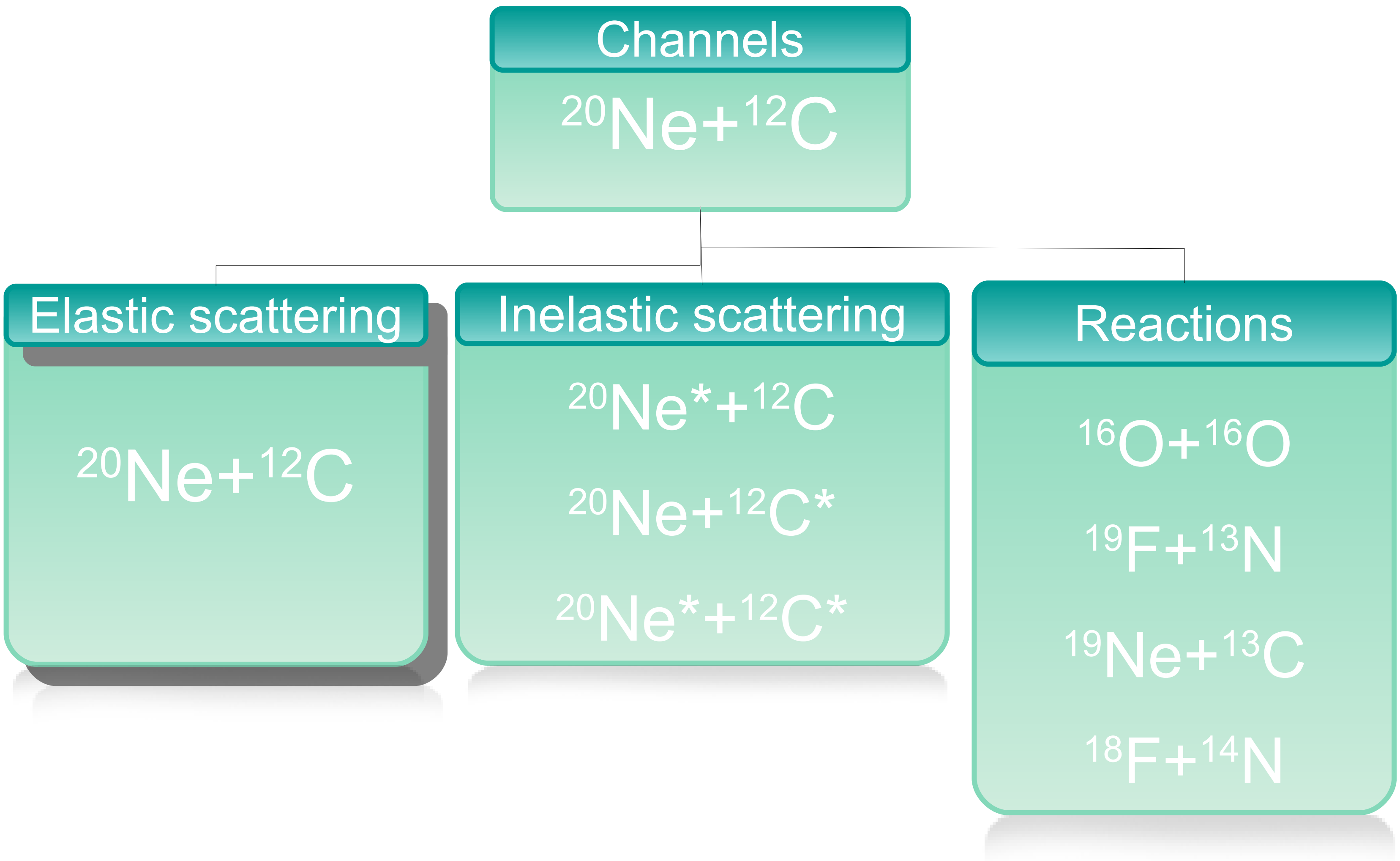
$^{19}F+^{13}N$

$^{19}Ne+^{13}C$

$^{18}F+^{14}N$

Basic classification

Elastic scattering



Elastic Scattering

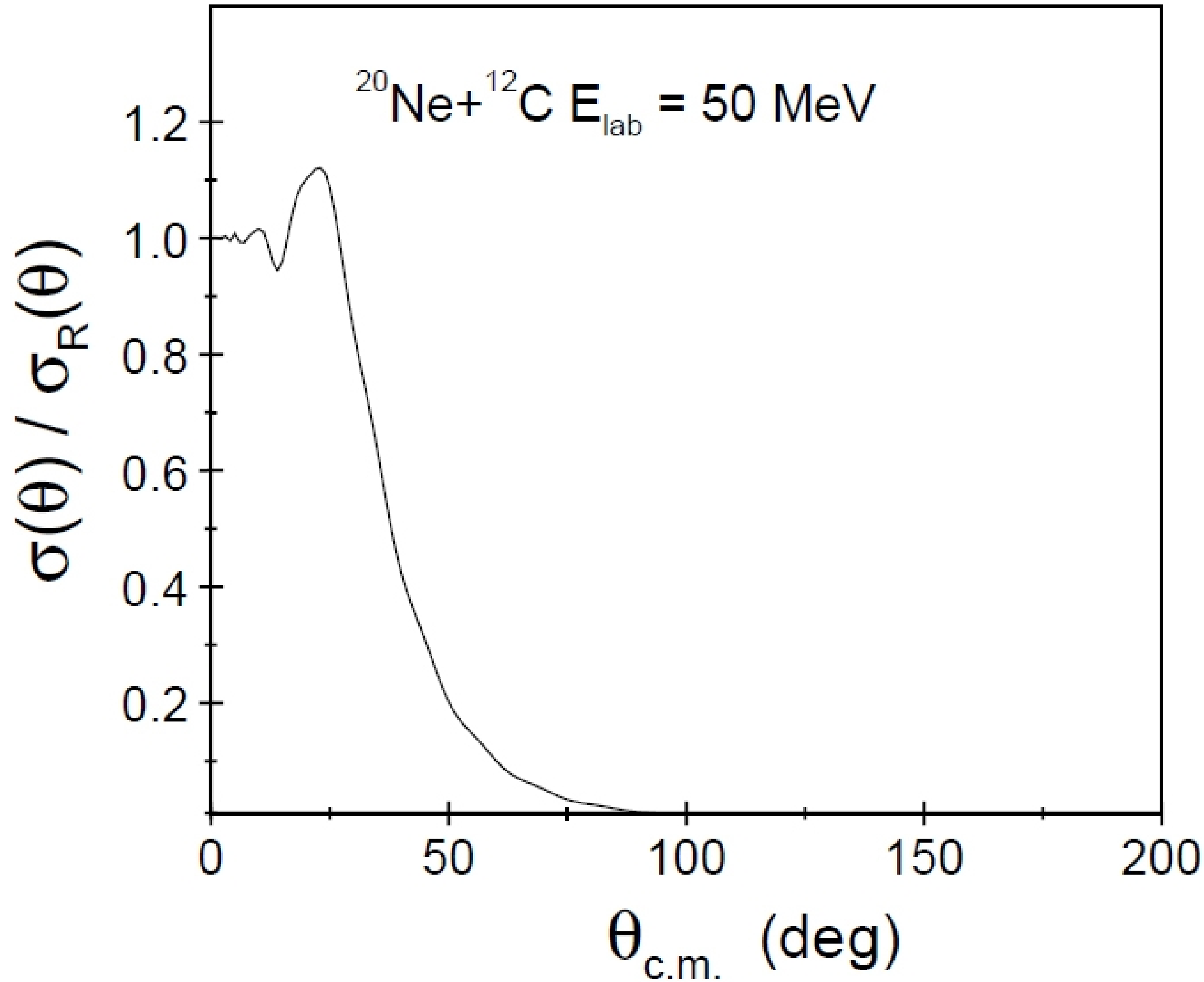
1. Phenomenological
2. Proton and α clusters
3. Double folding

Phenomenological

Elastic scattering

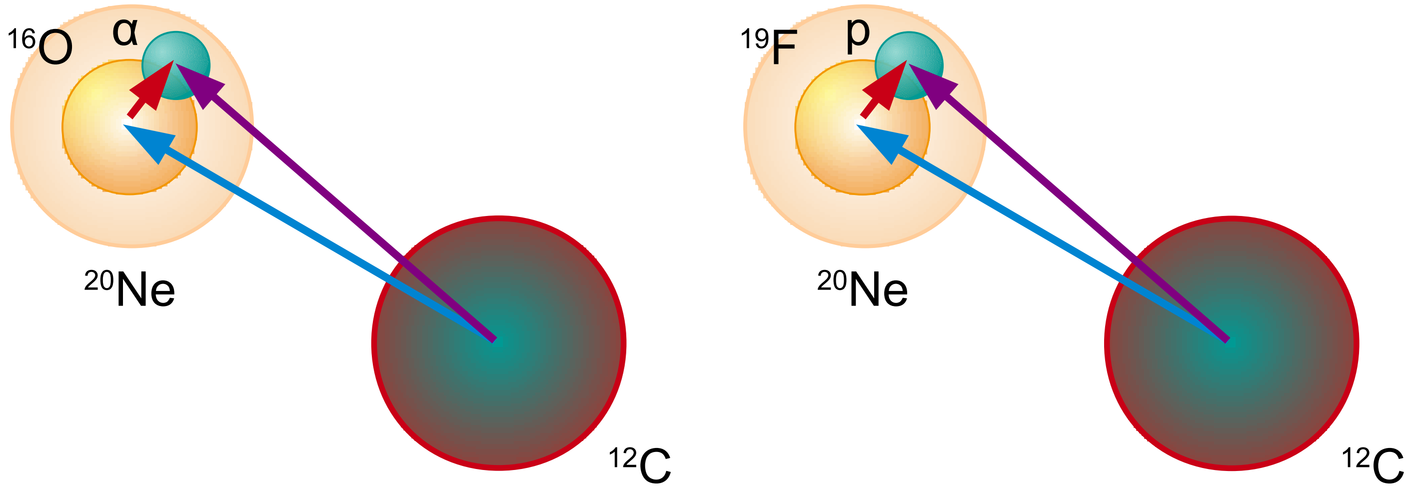
$^{20}Ne + ^{12}C \rightarrow ^{20}Ne + ^{12}C$

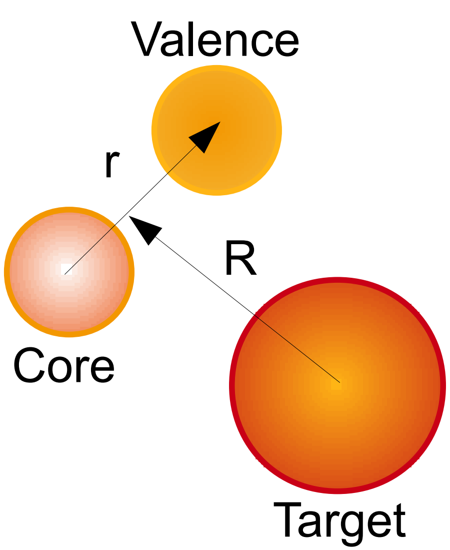
$$V(R) = [V+iW]/\{1+\exp[(R-R_0)/a]\}$$



α and proton clusters

Elastic scattering





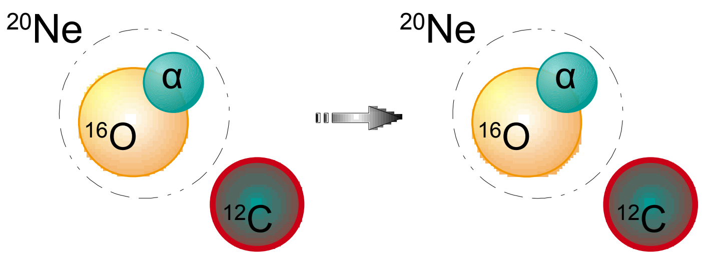
Cluster folding potential:

$$V(R) = \langle \varphi_i(r) | \, V(r,R) \, | \varphi_i(r) \rangle$$

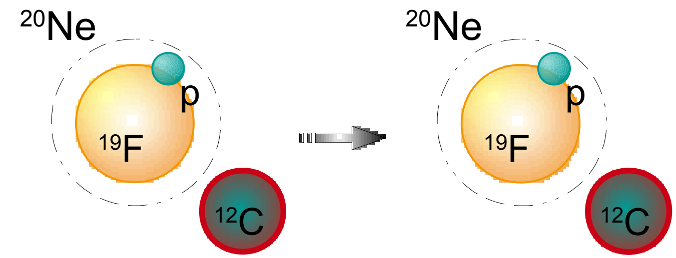
$$V(r,R) = V_{core,target}(r,R) + V_{valence,target}(r,R) + V_{core,valence}(r)$$

α and proton clusters

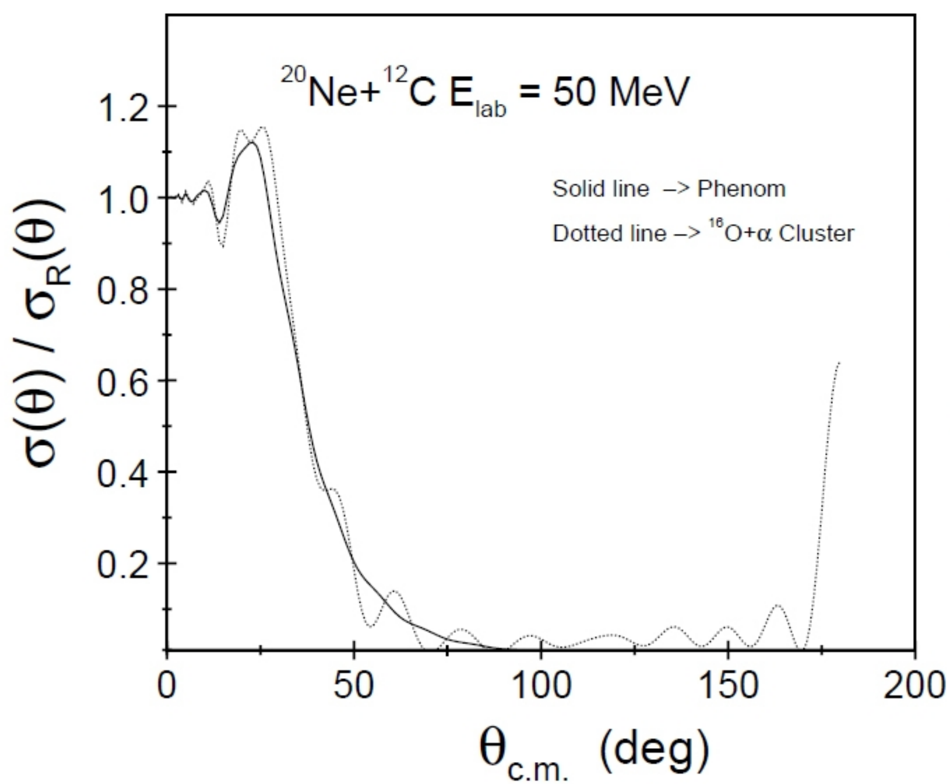
Results

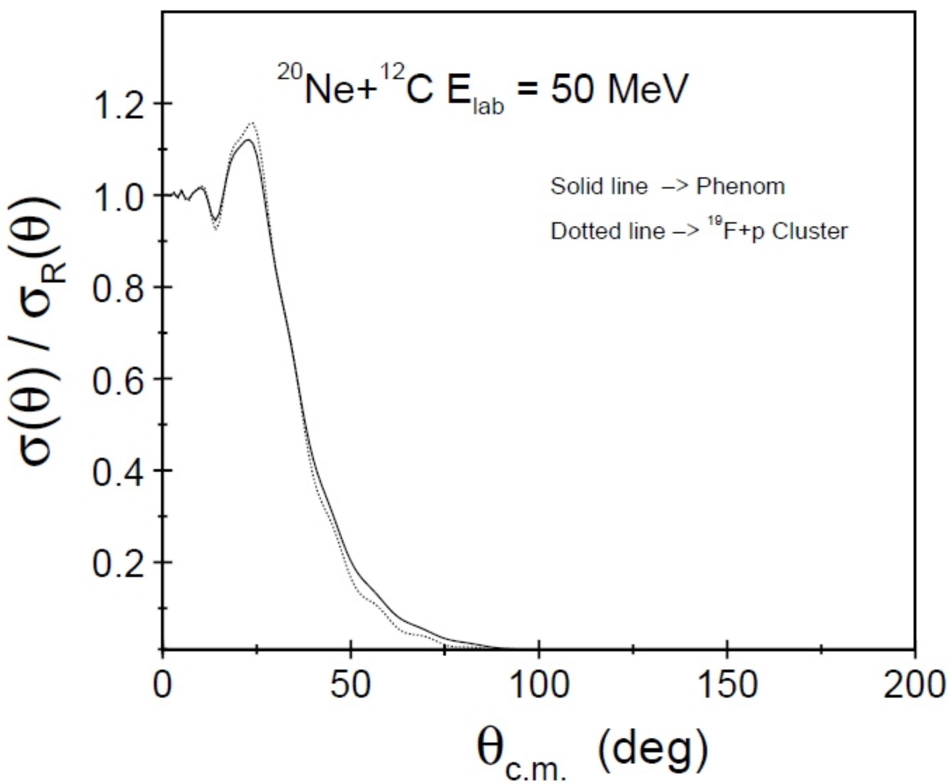


Alpha cluster



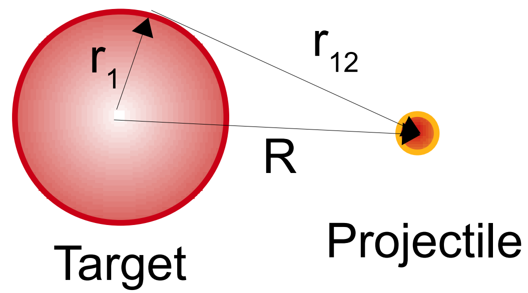
Proton cluster





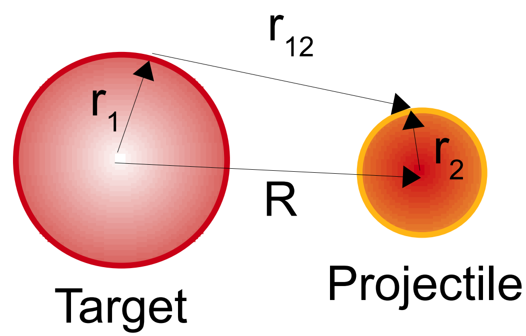
Single-folding potential

$$V(R)=\int dr_1 \rho_{target} v(r_{12})$$



Double-folding potential

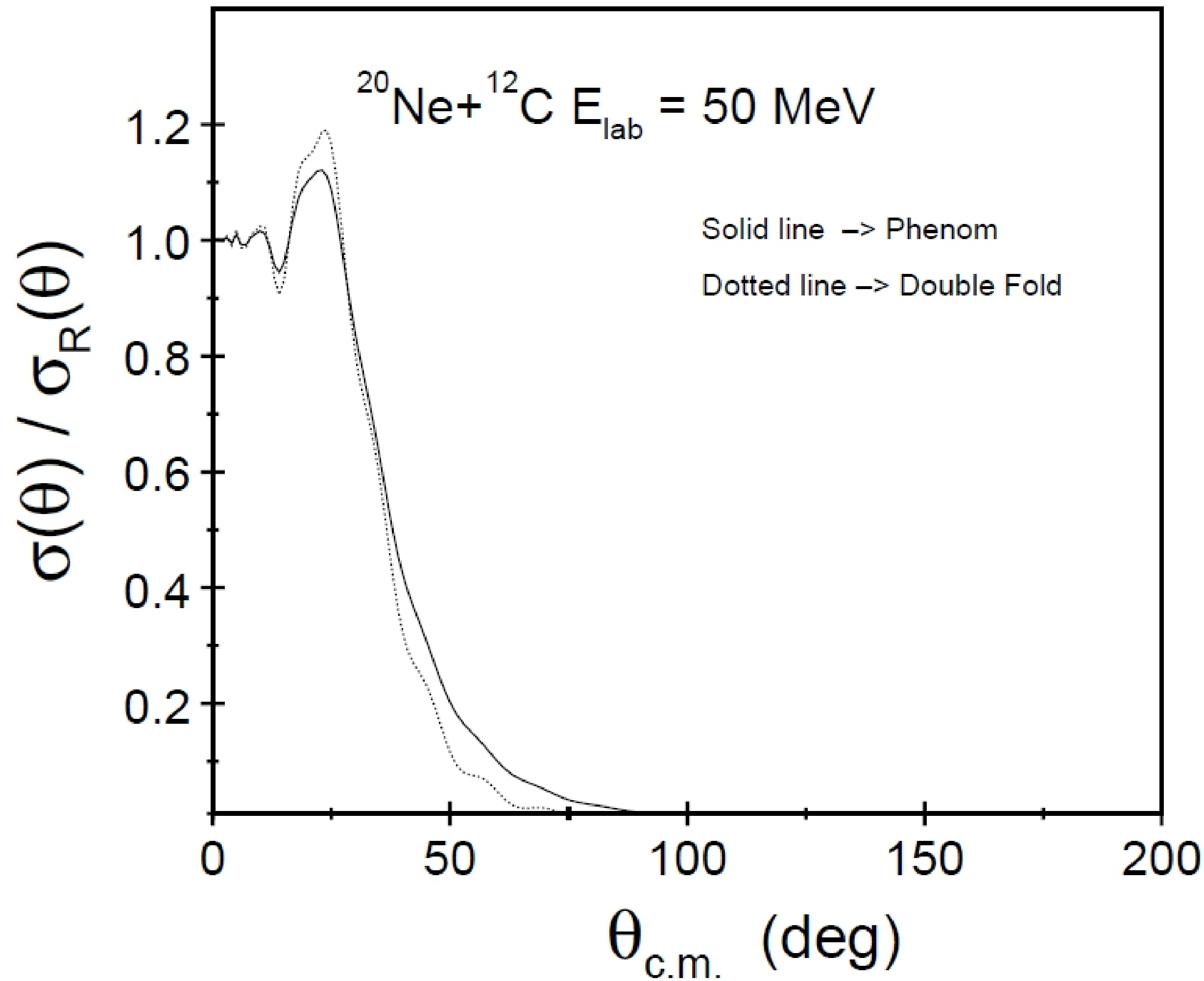
$$V(R)=\iint dr_1 dr_2 \rho_{projectile} \rho_{target} v(r_{12})$$



Imaginary potential W ?

Double folding
Elastic scattering

$^{20}Ne + ^{12}C \rightarrow ^{20}Ne + ^{12}C$



Basic classification

Channels

$^{20}Ne+^{12}C$

Elastic scattering

- $^{20}Ne+^{12}C$

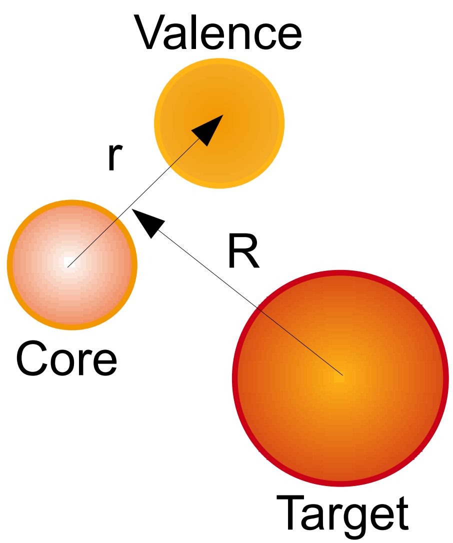
Inelastic scattering

- **$^{20}Ne^{*}+^{12}C$**
- $^{20}Ne+^{12}C^{*}$
- $^{20}Ne^{*}+^{12}C^{*}$

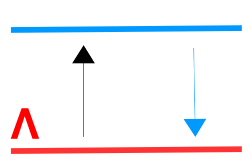
Reactions

- $^{16}O+^{16}O$
- $^{19}F+^{13}N$
- $^{19}Ne+^{13}C$
- $^{18}F+^{14}N$

Coupled channels Method



Projectile excitation



$$\psi(r,R) = \varphi_{g.s.}(r)\chi_{el}(R) + \varphi_{1exc}(r)\chi_{inel}(R) + ..$$

$$V(r,R) = V_{cent.}(R) + U(r,R)$$

$$[T + \varepsilon_{g.s.} - E + V_{cent.}(R) + \langle\varphi_{g.s.}(r)|\, U(r,R)\, |\varphi_{g.s.}(r)\rangle]\, \chi_{el}(R) = \langle\varphi_{g.s.}(r)|\, U(r,R)|\varphi_{1exc.}(r)\rangle\, \chi_{inel}(R)$$

Inelastic Scattering

Main factors

1. Coulomb excitation
2. Nuclear interaction
3. Combined effect

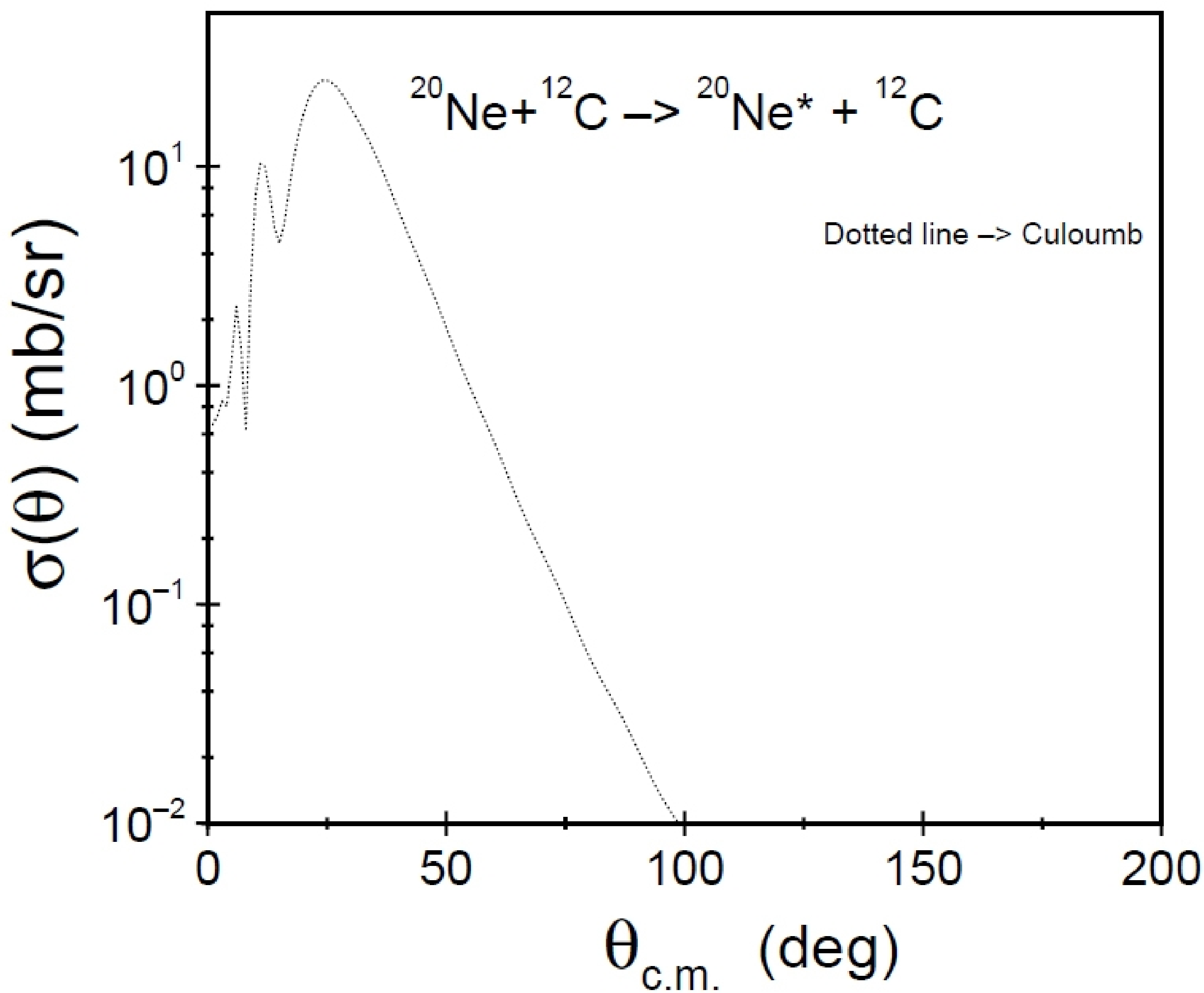
Coulomb excitation

^{20}Ne + ^{12}C → $^{20}Ne^*$ + ^{12}C

^{20}Ne levels

2^+ —— 1.633 MeV

0^+ —— 0 MeV



Nuclear interaction

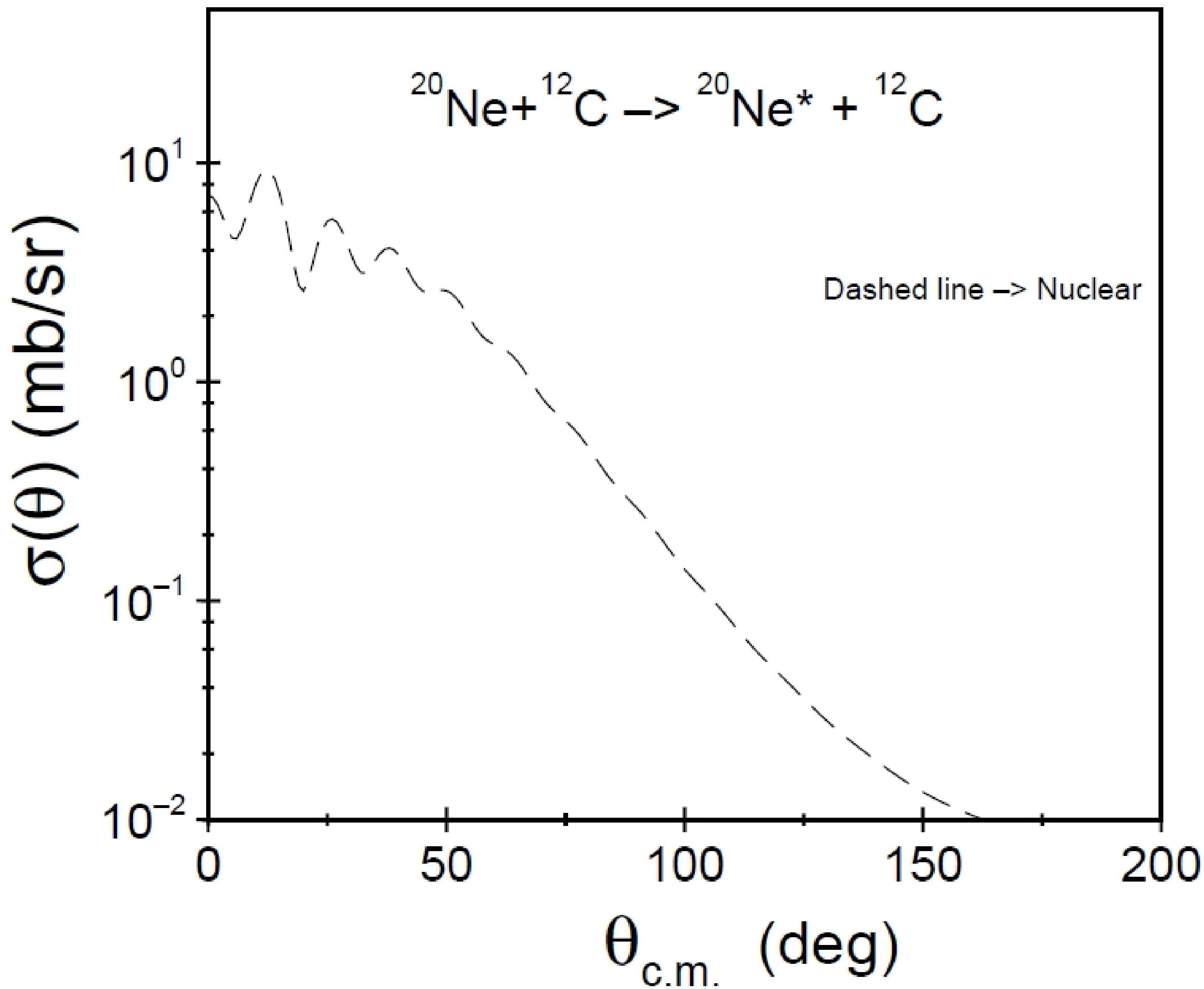
Results

$^{20}Ne + ^{12}C \rightarrow ^{20}Ne^{*} + ^{12}C$

^{20}Ne levels

2^{+} —— 1.633 MeV

0^{+} —— 0 MeV



Joint effect

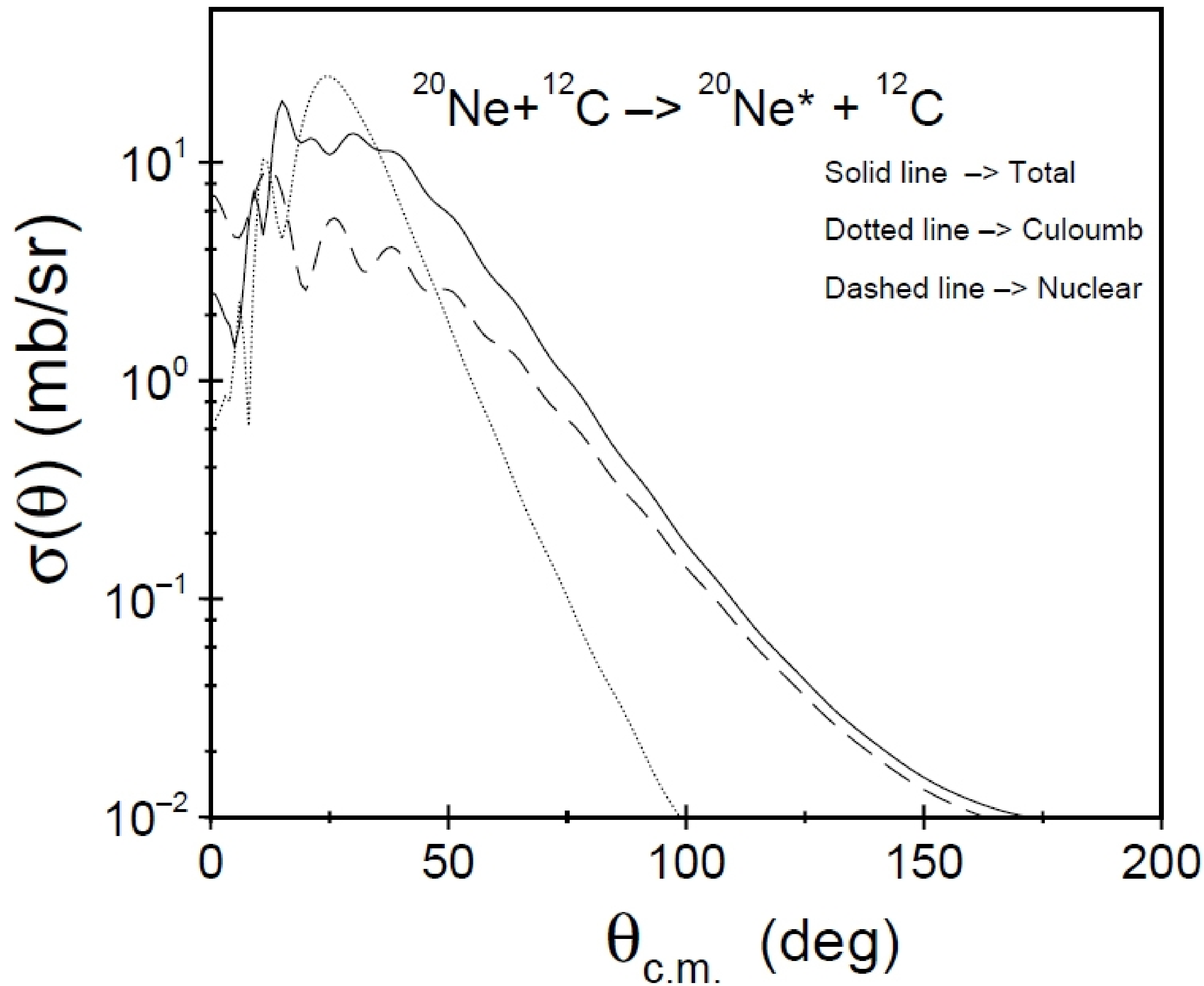
Results

^{20}Ne + ^{12}C → $^{20}Ne^*$ + ^{12}C

^{20}Ne levels

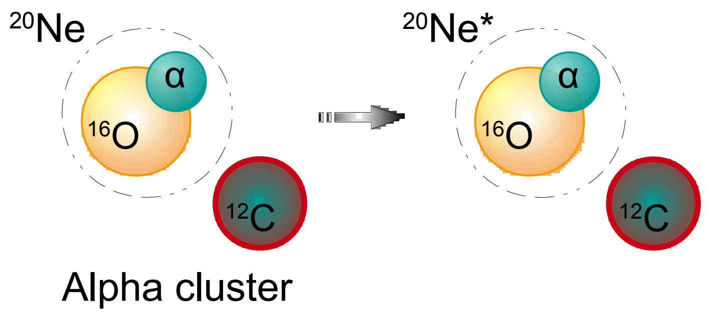
2^+ —— 1.633 MeV

0^+ —— 0 MeV

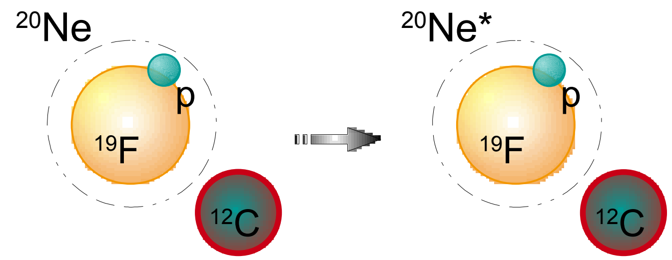


Double-folding and α / p clusters comparison

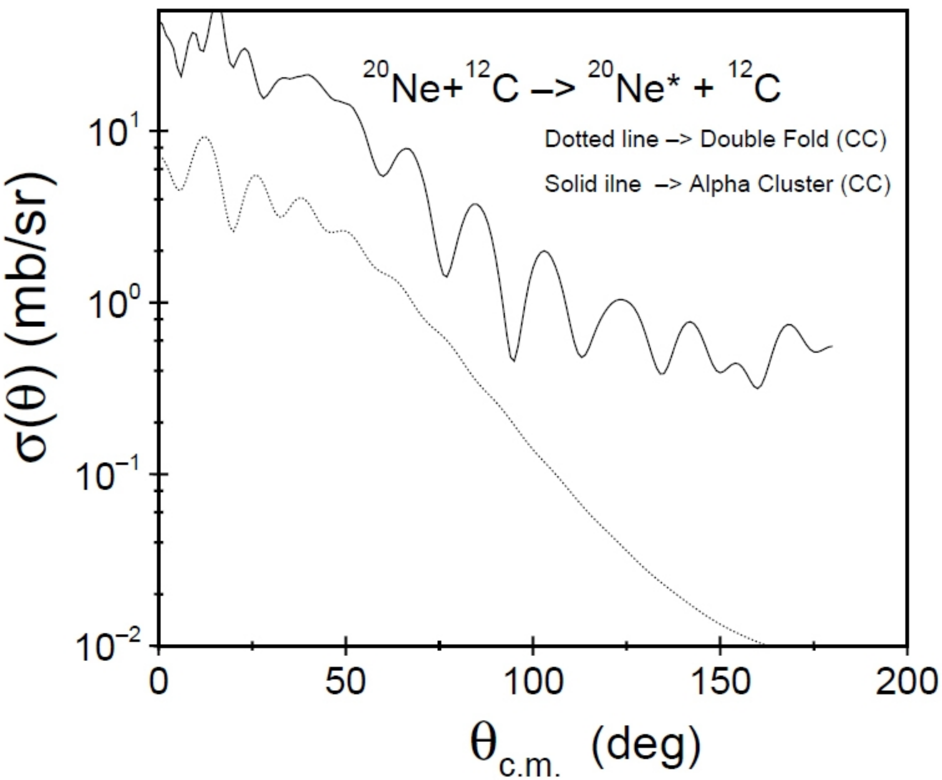
Results

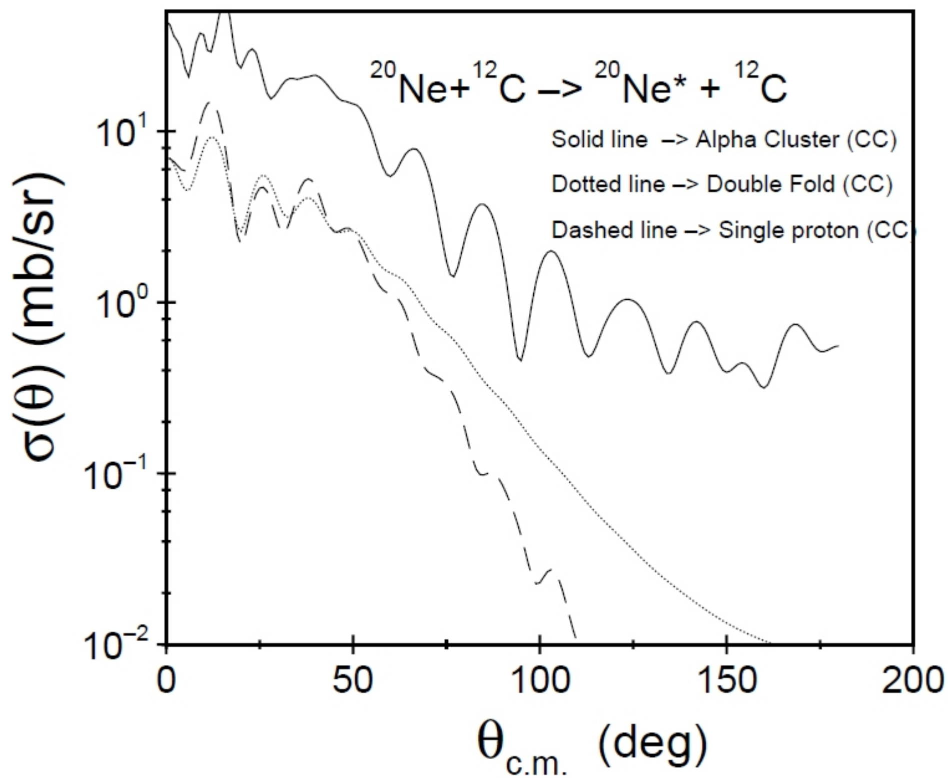


Alpha cluster



Proton cluster





Basic classification

Channels

$^{20}Ne+^{12}C$

Elastic scattering

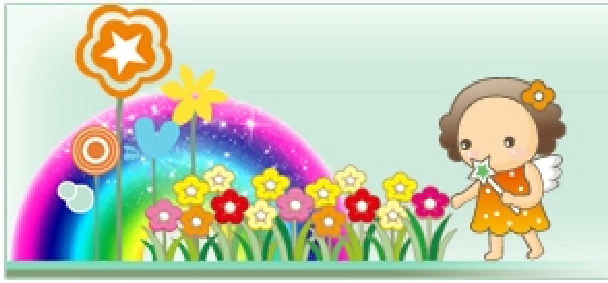
- $^{20}Ne+^{12}C$

Inelastic scattering

- $^{20}Ne^{*}+^{12}C$
- $^{20}Ne+^{12}C^{*}$
- $^{20}Ne^{*}+^{12}C^{*}$

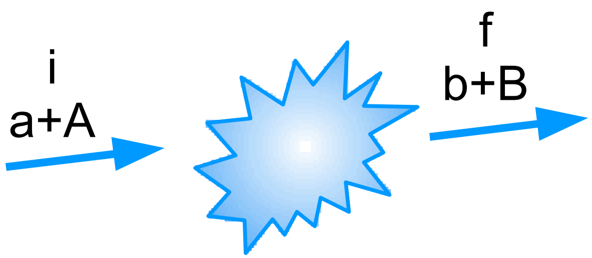
Reactions

- $^{16}O+^{16}O$
- $^{19}F+^{13}N$
- $^{19}Ne+^{13}C$
- $^{18}F+^{14}N$



DWBA
The next theoretical model

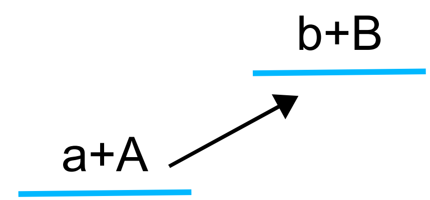
DWBA (Distorted Wave Born Approximation): TRANSFER REACTIONS



$$P_{i\to f} \sim |\langle \varphi_i \chi_{aA} | U | \varphi_f \chi_{bB} \rangle|^2$$

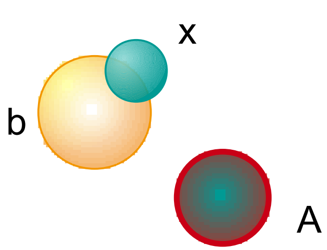
where: $\varphi_i = \varphi_a \varphi_A$

$\varphi_f = \varphi_b \varphi_B$



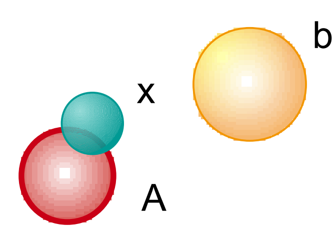
$V(R,r) = V_{cent.}(R) + U(R,r)$ **where** $U(R,r) \ll V_{cent.}(R)$

$U(R,r) = | V(R,r) - V_{cent.}(R) |$



Post:

$U = V_{bx} + V_{bA} - V_{bB} \sim V_{bx}$

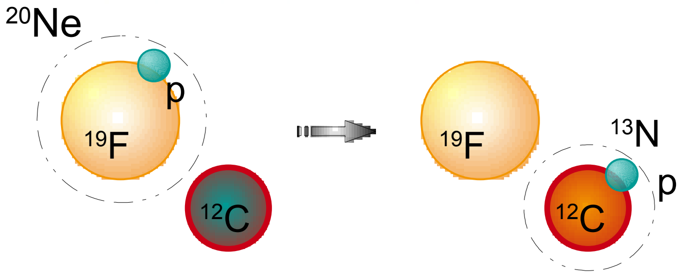


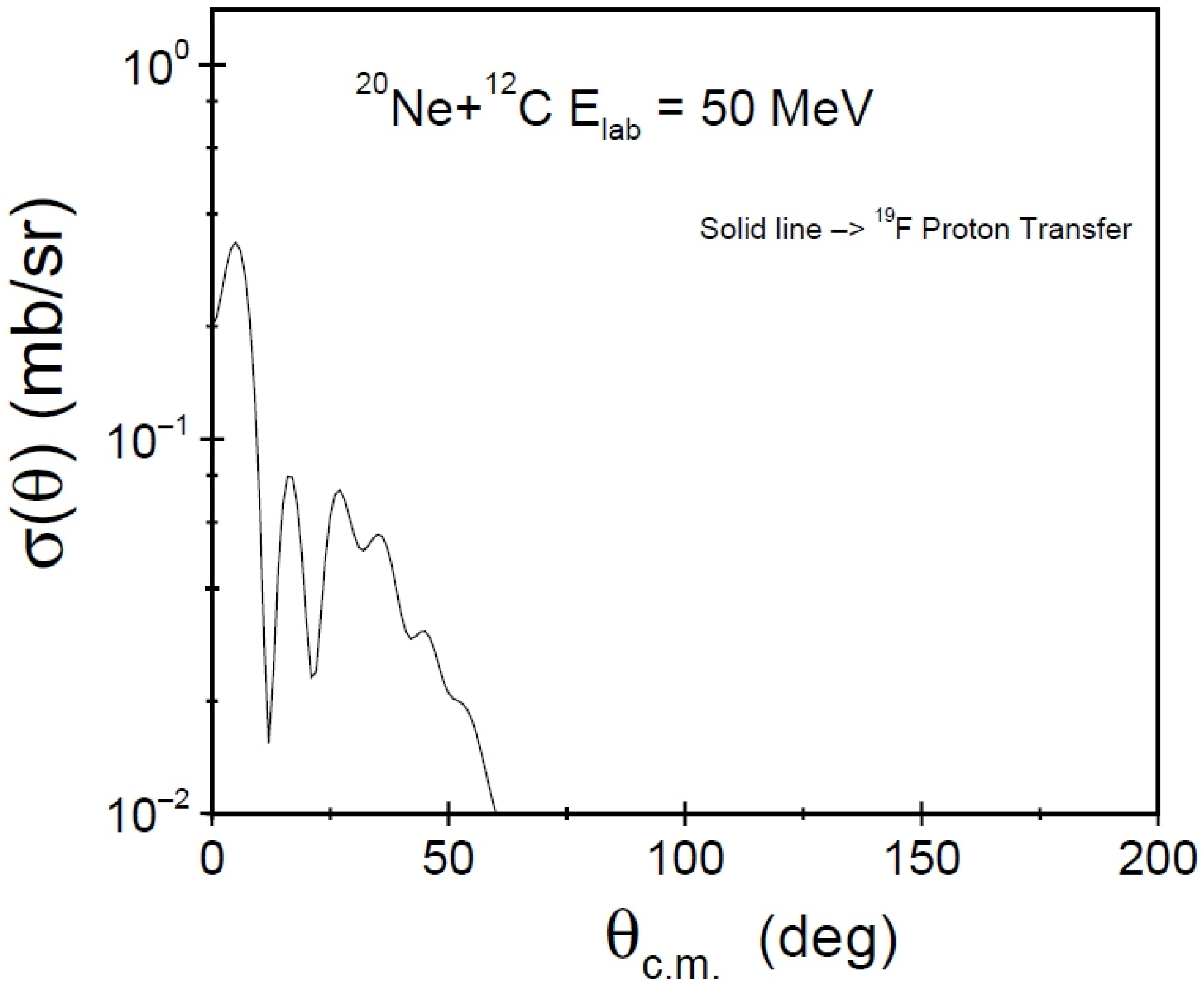
Prior:

$U = V_{bA} + V_{xA} - V_{aA} \sim V_{xA}$

Proton transfer

$^{20}Ne + ^{12}C \rightarrow ^{19}F + ^{13}N$

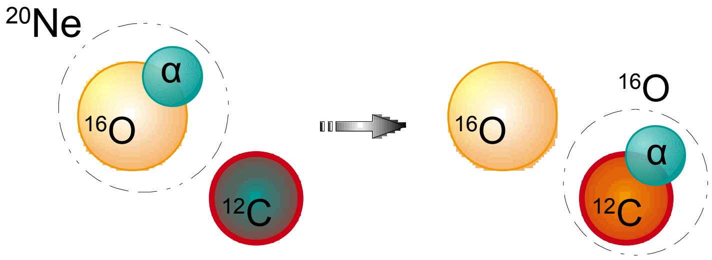


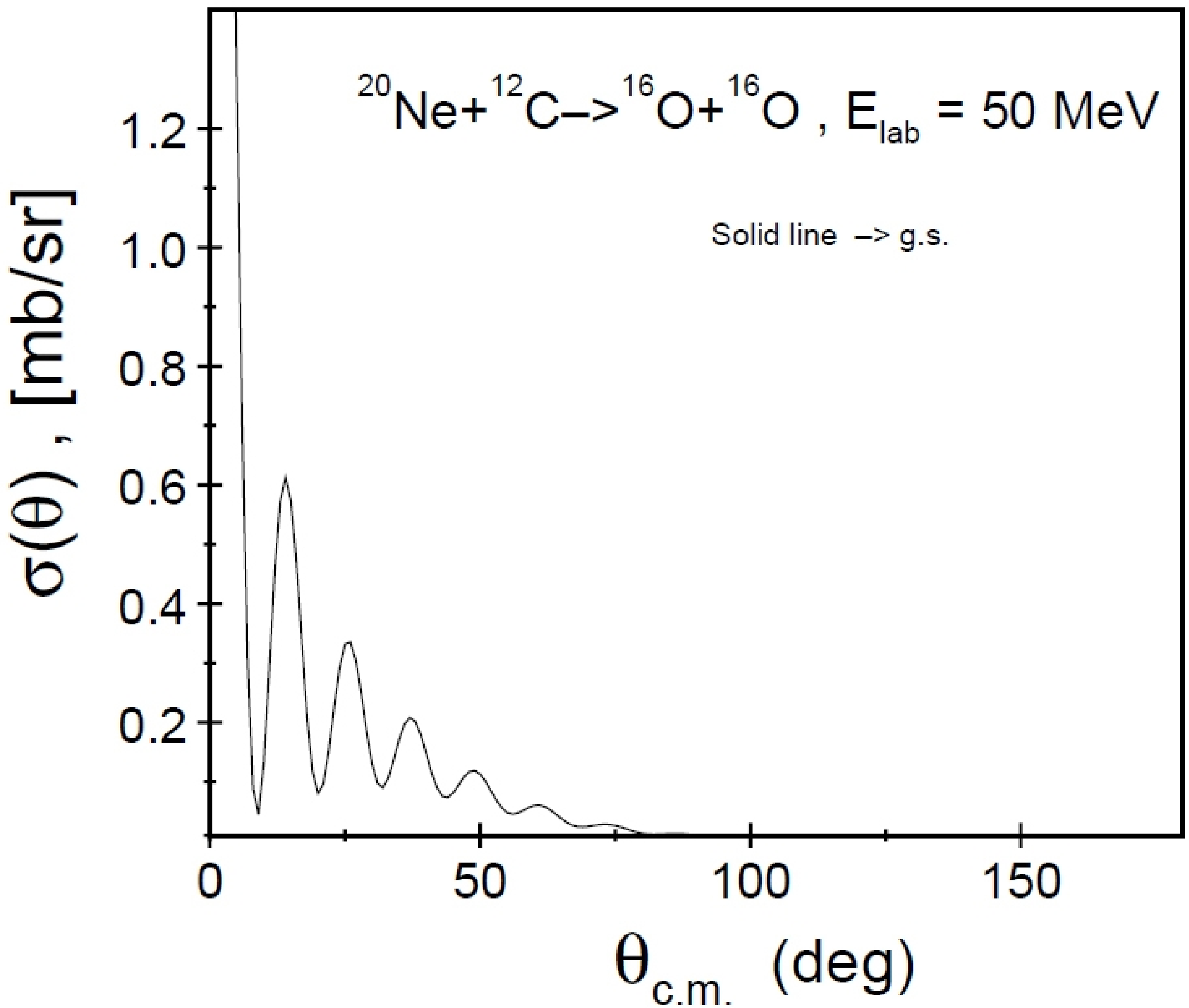


α transfer

$^{20}Ne + ^{12}C \rightarrow ^{16}O + ^{16}O$

Ground state

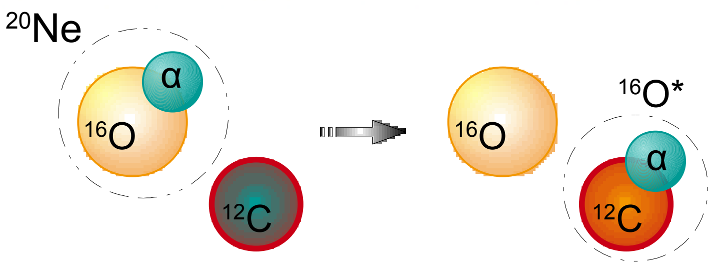


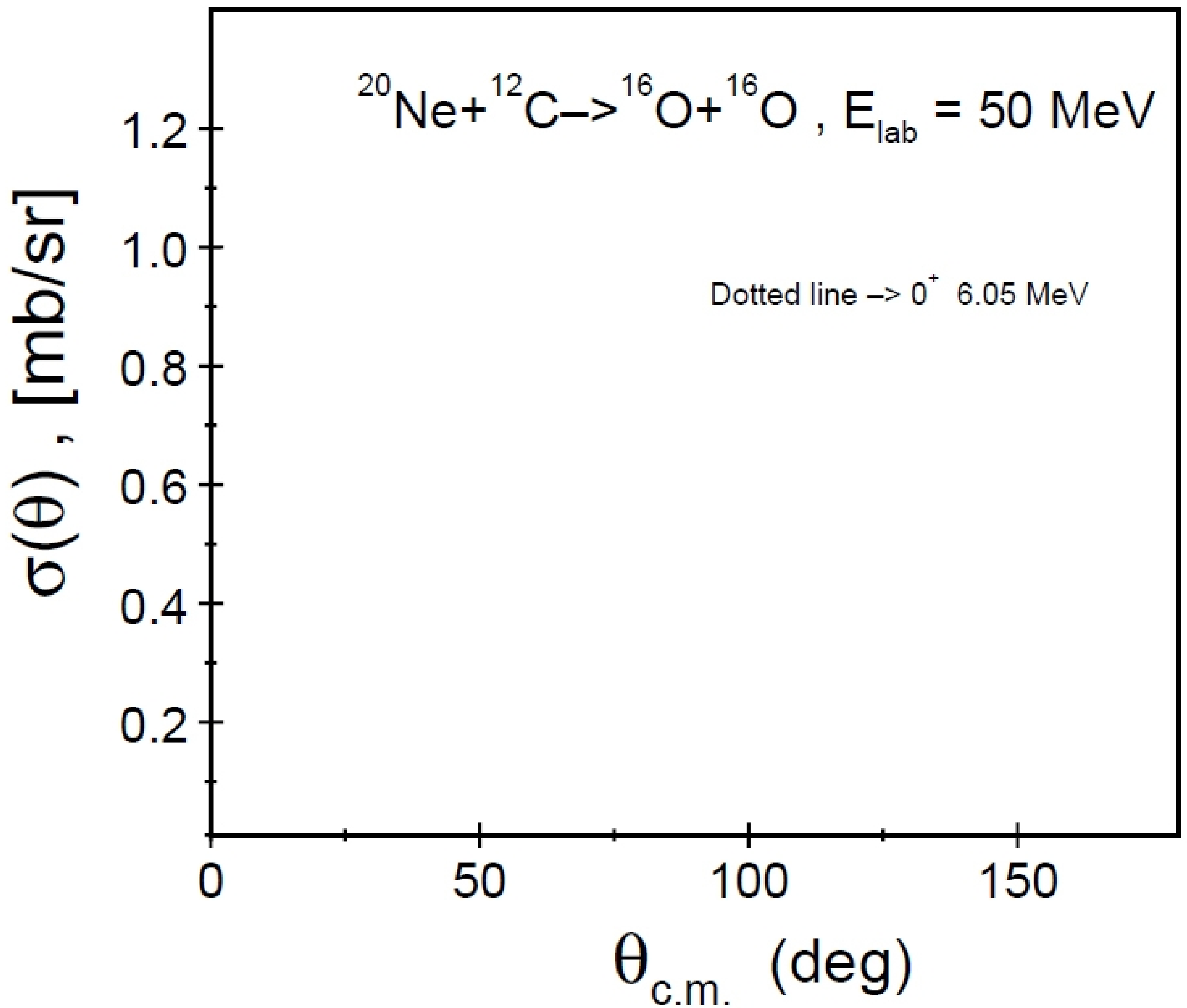


α transfer

$^{20}Ne + ^{12}C \rightarrow ^{16}O + ^{16}O$

0^+ state

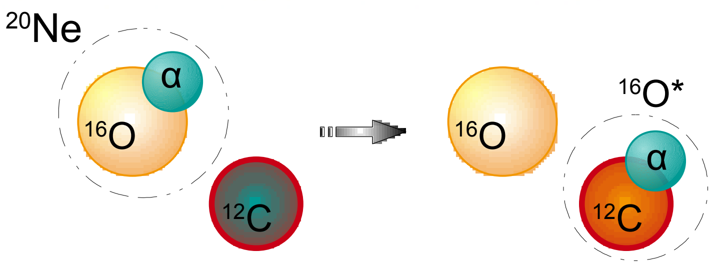


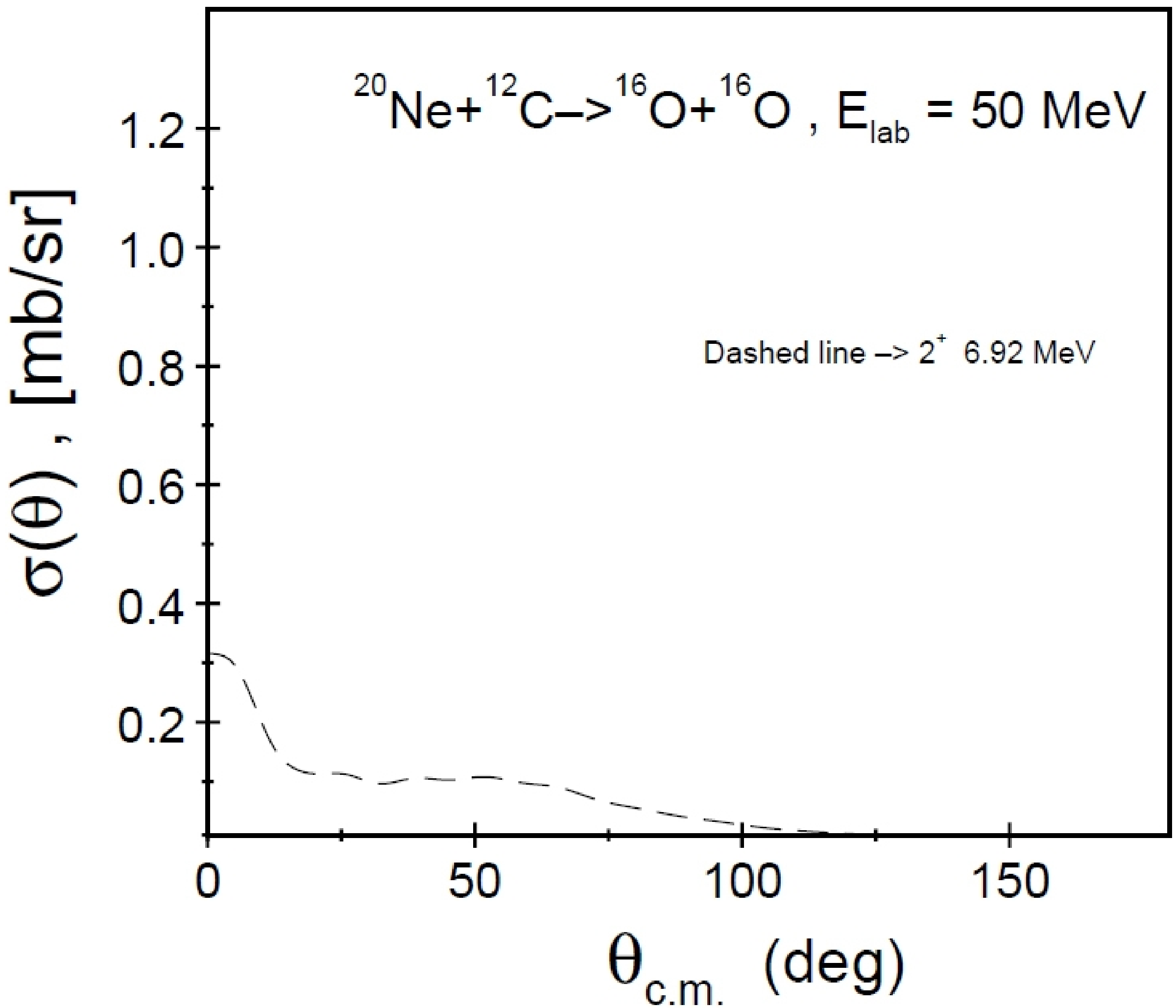


α transfer

$^{20}Ne + ^{12}C \rightarrow ^{16}O + ^{16}O$

2^+ state

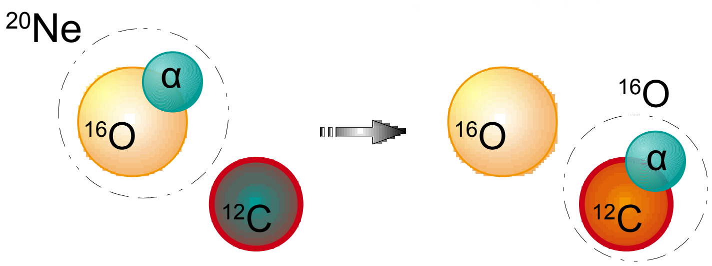


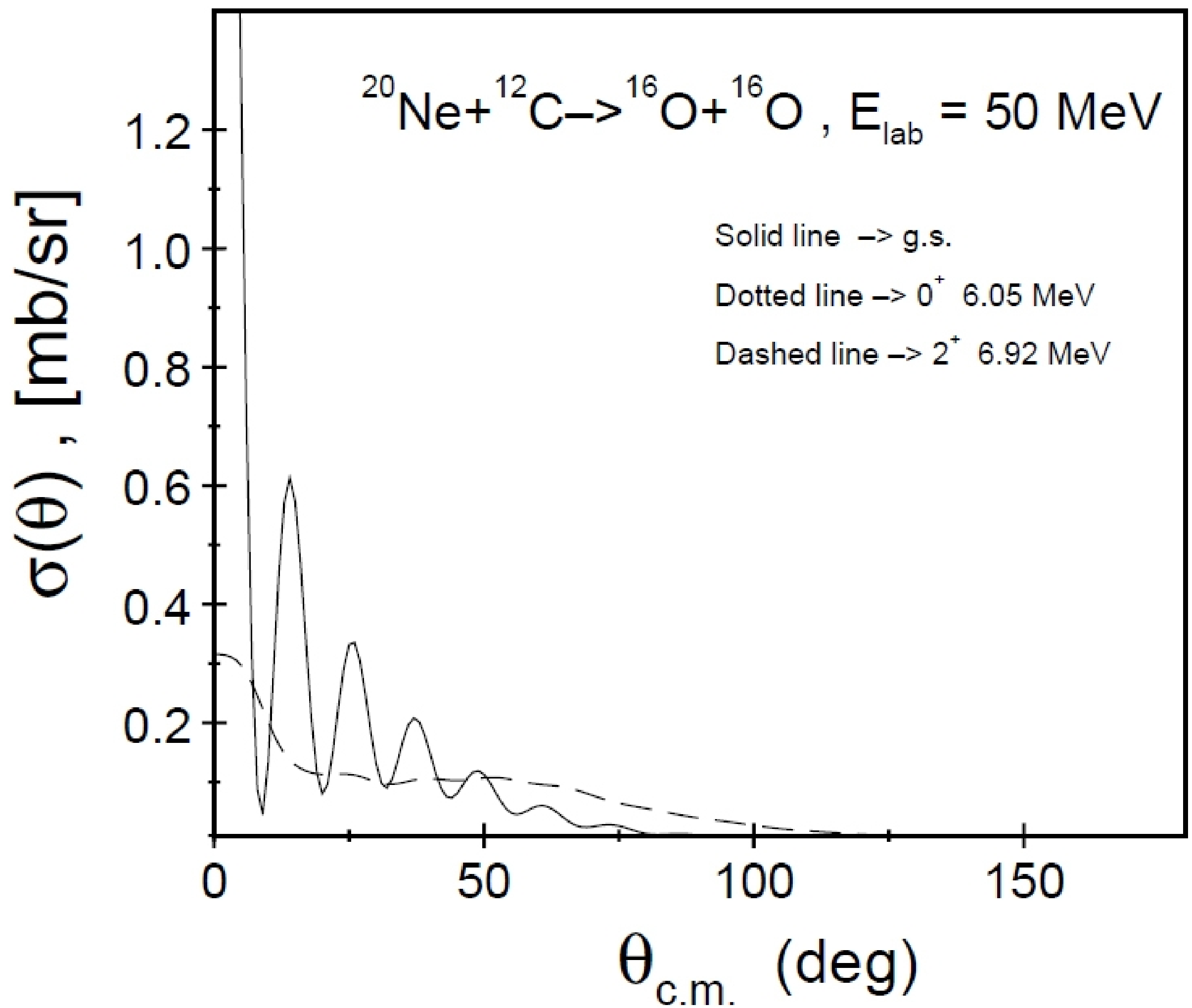


α transfer

$^{20}Ne+^{12}C \rightarrow {}^{16}O + {}^{16}O$

Results





Take-a-break-slide

We have not finished yet

Thank you !