Reaction cross section　について

Glauber and Eikonal approximations

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Quantum-mechanical theory of optical coherence

Nobel prize in physics, 2005

http://www.physics.harvard.edu/people/facpages/glauber.html

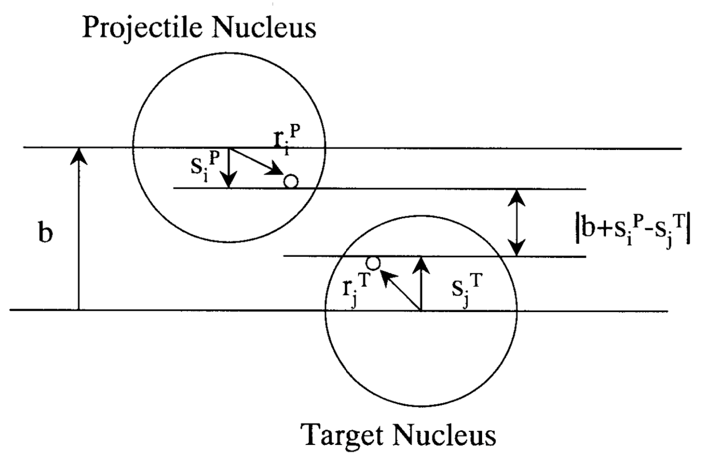
Glauber theory

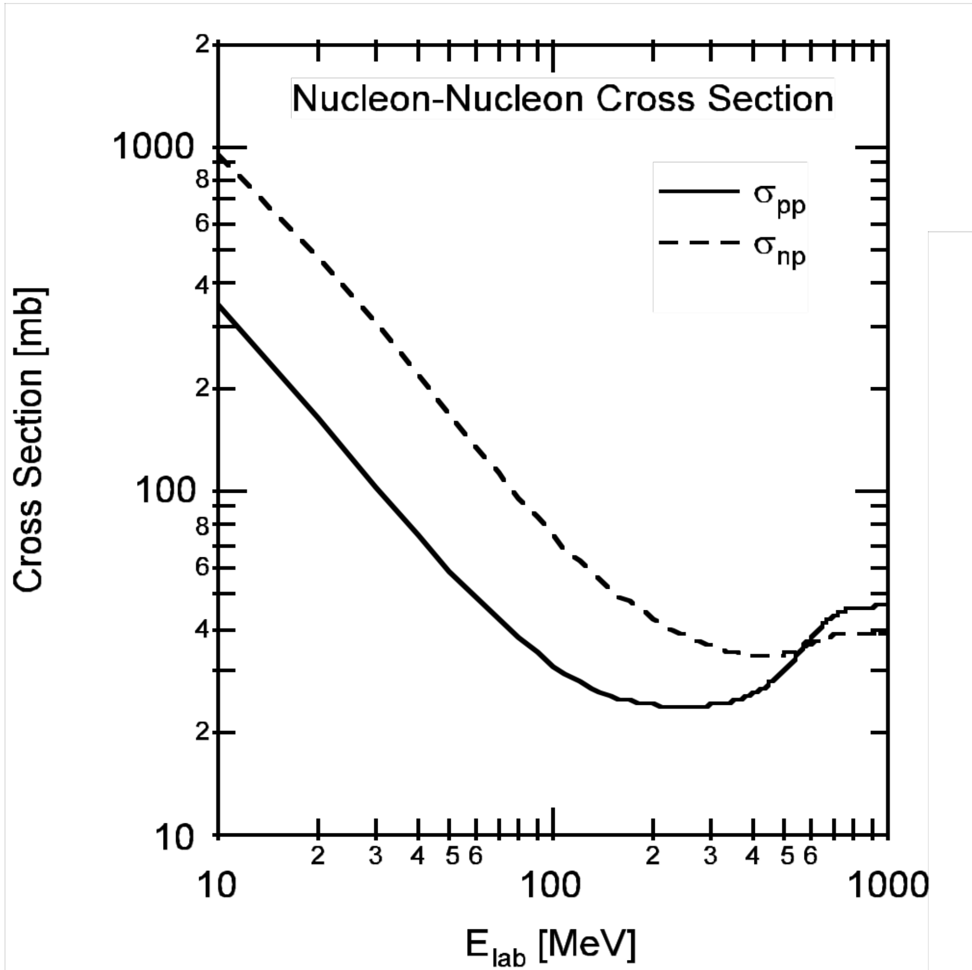
Nucleus-nucleus phase shift function

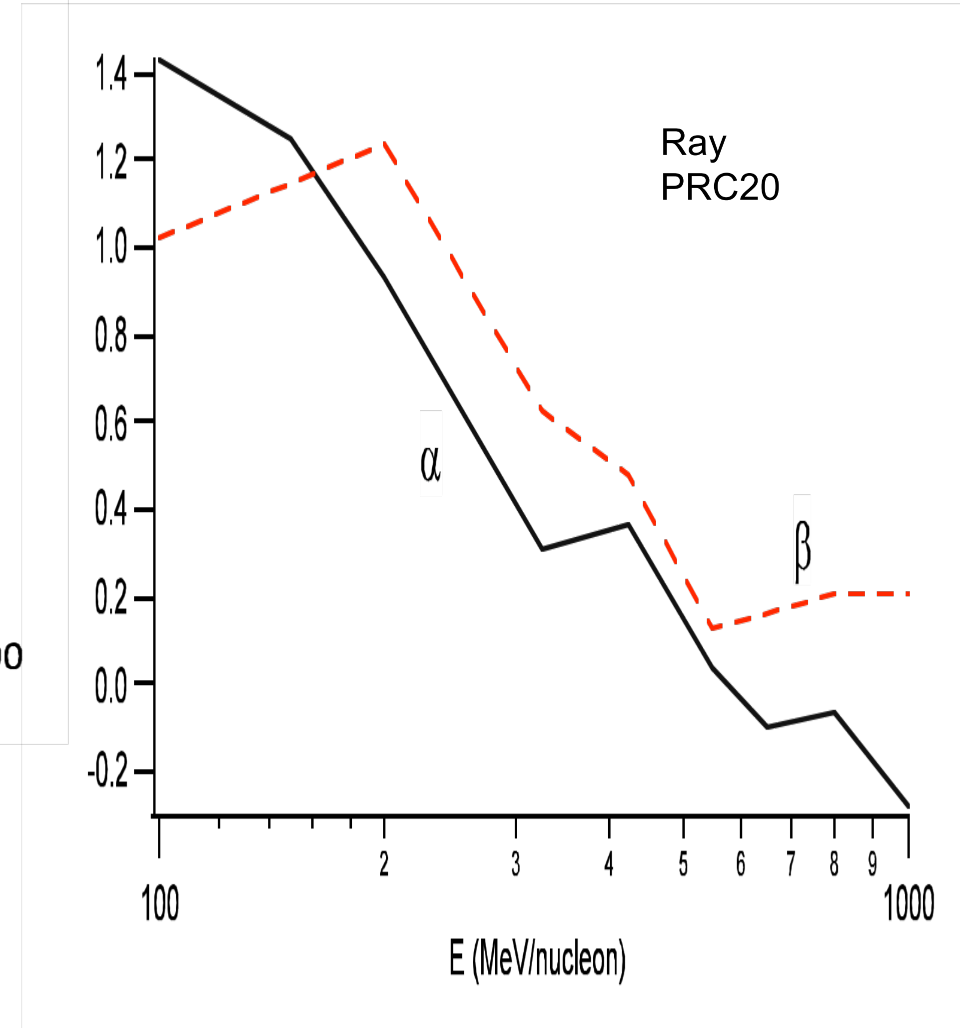
$$e^{i\chi(\mathbf{b})} = \langle \psi_0 \theta_0 | \prod_{i \in P} \prod_{j \in T} (1 - \Gamma_{NN}(\boldsymbol{\xi}_i - \boldsymbol{\eta}_j + \mathbf{b})) | \psi_0 \theta_0 \rangle$$

$$\Gamma(\boldsymbol{b}) = \frac{\sigma_\tau}{4\pi\beta_\tau}(1 - i\alpha_\tau)\exp\left(-\frac{\boldsymbol{b}^2}{2\beta_\tau}\right)$$

$$\sigma_{\mathrm{reac}} = \int d\boldsymbol{b}(1 - |e^{i\chi_{\mathrm{el}}(\boldsymbol{b})}|^2)$$




Nucleon-Nucleon Cross Section
σ_{pp}
σ_{np}
Cross Section [mb]
E_{lab} [MeV]
10
100
1000


Ray
PRC20
α
β
E (MeV/nucleon)
100
1000

Calculation of PSF

多重積分をモンテカルロ法で近似なしに計算可能： Phys. Rev. C66, 034611
高精度の波動関数を直接使用できるので有利

Using density of nucleus

$$e^{i\chi_{\mathrm{OLA}}(\mathbf{b})} = \exp\left\{ -\int \int d\mathbf{r}\, d\mathbf{s}\, \rho_P(\mathbf{r})\rho_T(\mathbf{s})\Gamma_{NN}(\boldsymbol{\xi} - \boldsymbol{\eta} + \mathbf{b}) \right\}$$

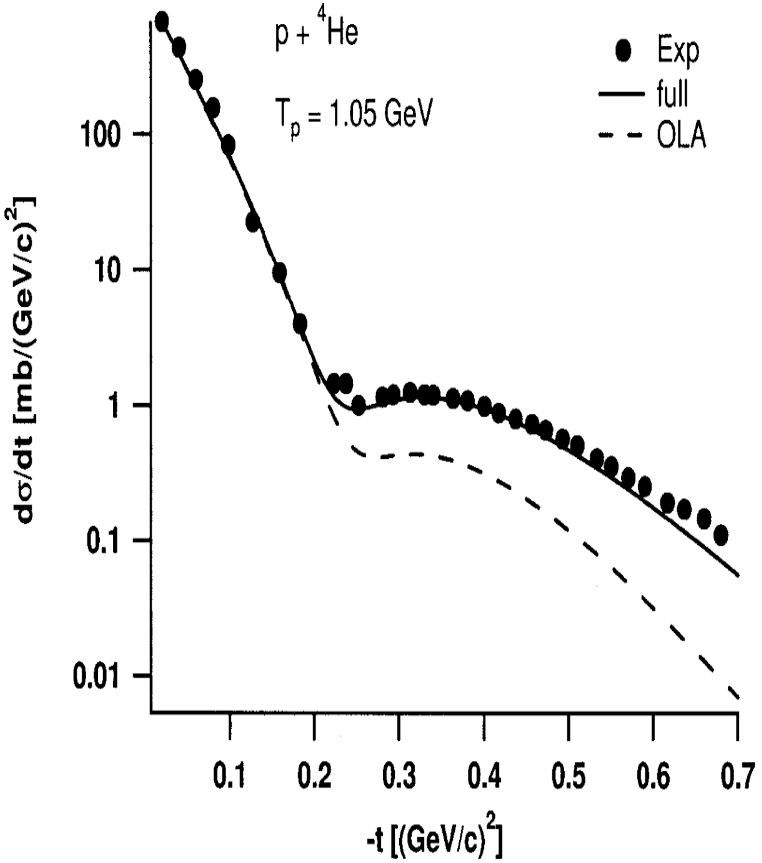
B. Abu-Ibrahim, Y.Suzuki, PRC61

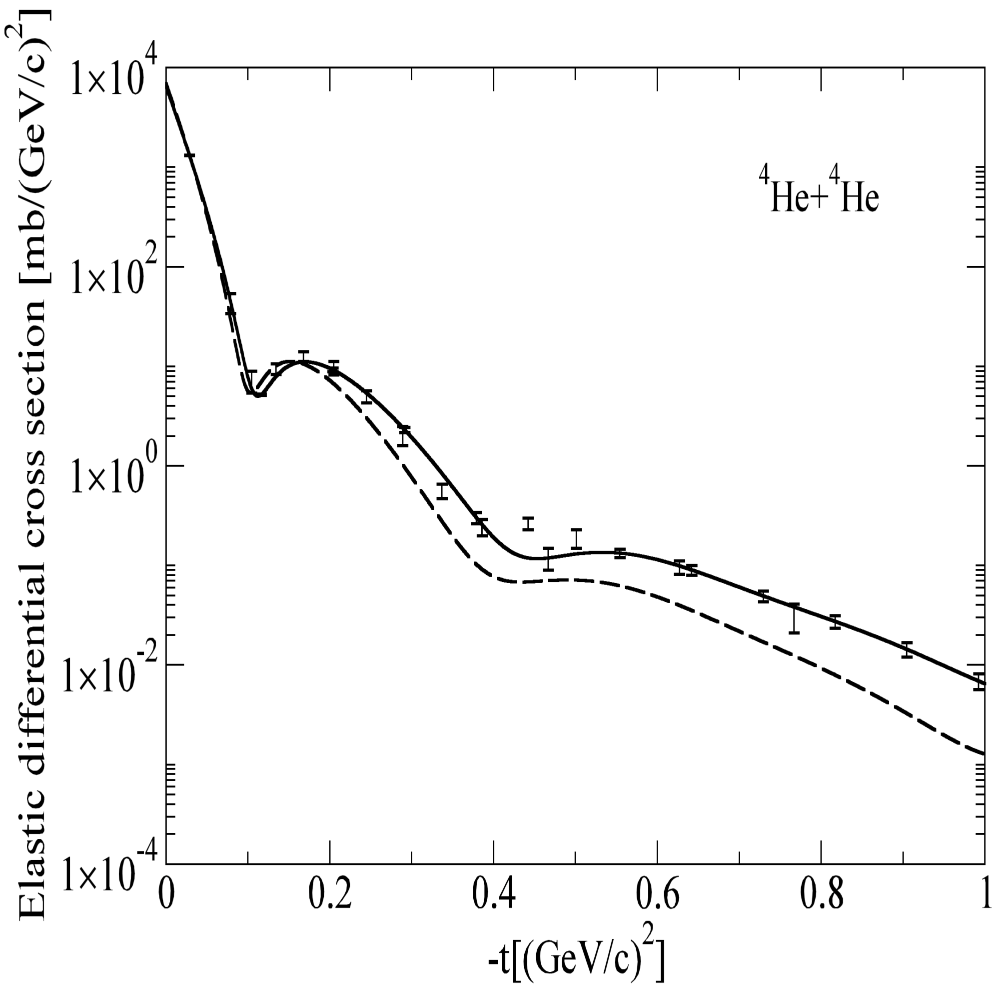
Use of N-target optical potential

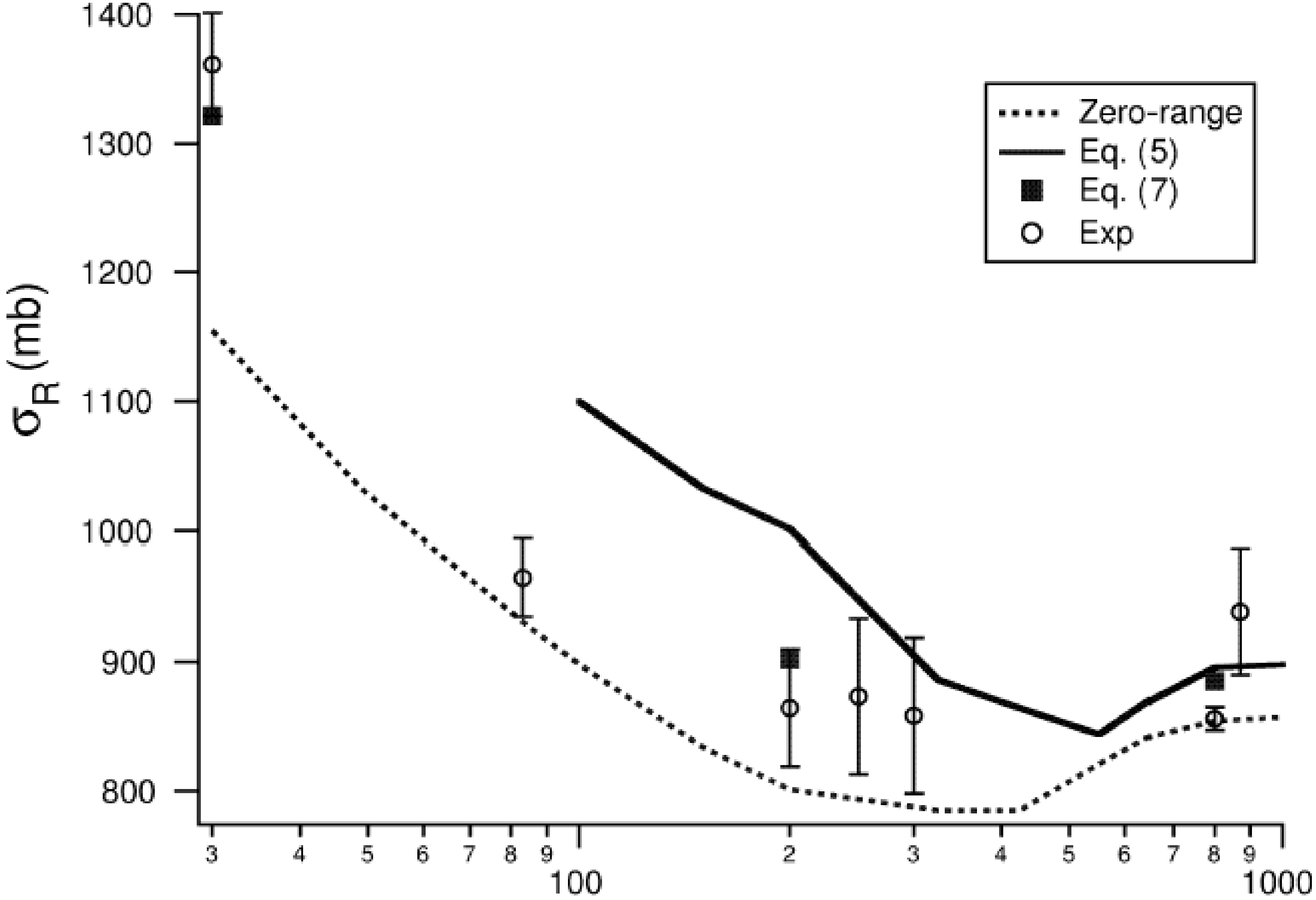
$$\chi_{\mathrm{NT}}(\mathbf{b}) = -\frac{\mu}{\hbar^2 K} \int_{-\infty}^{\infty} \mathrm{d}z\, U_{\mathrm{NT}}(\mathbf{b} + z\mathbf{e}_z)$$

$$\Gamma_{\mathrm{NT}} = 1 - \mathrm{e}^{\mathrm{i}\chi_{\mathrm{NT}}}$$

$$\mathrm{e}^{\mathrm{i}\tilde{\chi}_{\mathrm{OLA}}(\mathbf{b})} = \exp\left\{ -\int \mathrm{d}\mathbf{r}\, \rho_{\mathrm{P}}(\mathbf{r})\Gamma_{\mathrm{NT}}(\mathbf{s} + \mathbf{b}) \right\}$$


p + ^{4}He
T_p = 1.05 GeV
Exp
full
OLA
dσ/dt [mb/(GeV/c)^2]
100
10
1
0.1
0.01
0.1
0.2
0.3
0.4
0.5
0.6
0.7
-t [(GeV/c)^2]


^{4}He+^{4}He
Elastic differential cross section [mb/(GeV/c)^2]
1×10^4
1×10^2
1×10^0
1×10^{-2}
1×10^{-4}
0
0.2
0.4
0.6
0.8
1
-t[(GeV/c)^2]



$^{12}C + ^{12}C$ reaction cross sections reaction cross sections of He, Li and Be isotopes on a ^{12}C target at 800 MeV/nucleon

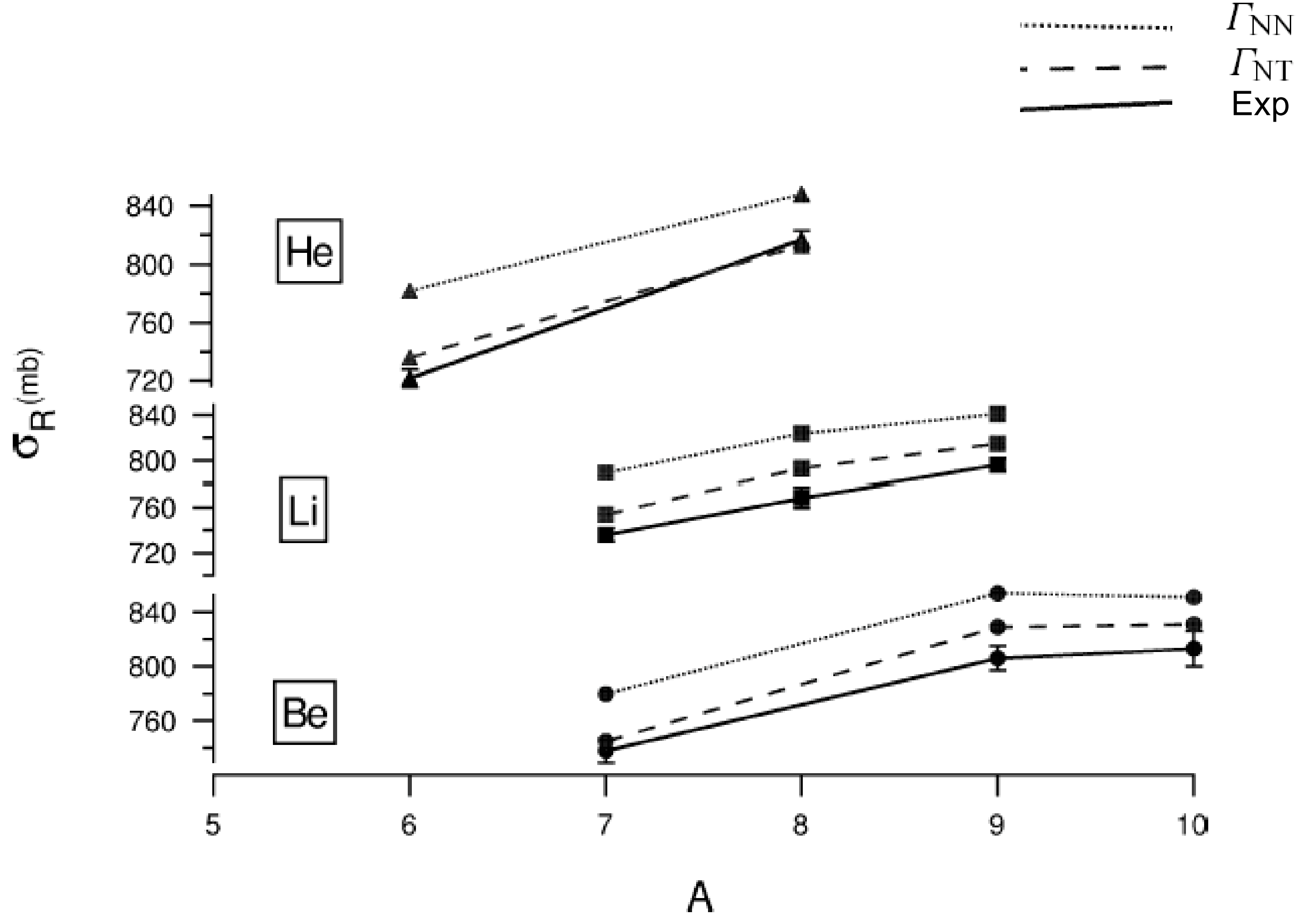


Table 3
Reaction cross sections, in units of mb, on a ^{12}C target at 200 MeV/nucleon

Projectile	Eq. (7)	Eq. (5)	Exp.
^{6}He	709	817	–
^{7}Li	738	850	–
^{7}Be	733	842	–
^{8}He	800	905	–
^{8}Li	785	893	–
^{8}B	789	896	–
^{9}Li	815	919	–
^{9}Be	827	932	–
^{9}C	850	954	–
^{10}Be	838	941	–
^{12}C	902	1002	864 ± 45
^{27}Al	1327	1410	1270 ± 70

The phase shift functions are calculated in two different approximations, Eqs. (5) and (7). The data are the reaction cross sections taken from [15].

In case no optical potential available

$$e^{i\tilde{\chi}_{\mathrm{OLA}}(\mathbf{b})} = \exp\left\{-\int d\mathbf{r}\,\rho_{\mathrm{P}}(\mathbf{r})\,\Gamma_{\mathrm{NT}}(\mathbf{s}+\mathbf{b})\right\}$$

$$\Gamma_{NT}(\mathbf{b}) \approx 1-\exp\left(-\int d\mathbf{s}\,\rho_T(\mathbf{s})\Gamma_{NN}(\mathbf{b}-\boldsymbol{\eta})\right)$$

$$e^{i\chi_{\mathrm{eff}}(\mathbf{b})} = \exp\left[-\int d\mathbf{r}\,\rho_P(\mathbf{r})\left\{1-\exp\left(-\int d\mathbf{s}\,\rho_T(\mathbf{s})\Gamma_{NN}(\boldsymbol{\xi}-\boldsymbol{\eta}+\mathbf{b})\right)\right\}\right]$$

TABLE I. A comparison of the theoretical reaction cross sections, in units of mb, with the interaction cross sections measured at 800 MeV/nucleon [1]. The phase shift functions are calculated in three different approximations [Eqs. (2), (8), and (9)].

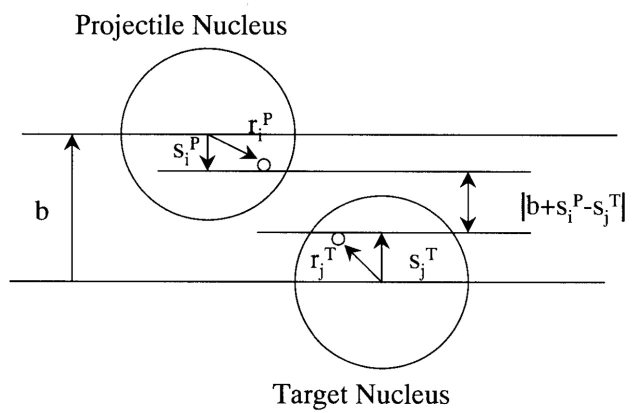
Target/projectile		^{4}He	^{6}He	^{9}Be	^{12}C
^{9}Be	Eq. (2)	488	716	805	
	Eq. (8)	461	660	765	
	Eq. (9)	453	672	765	
	Exp.	485 ± 4	672 ± 7	755 ± 5	
^{12}C	Eq. (2)	520	782	854	896
	Eq. (8)	490	707	804	856
	Eq. (9)	487	732	813	856
	Exp.	503 ± 5	722 ± 6	806 ± 9	856 ± 9
^{27}Al	Eq. (2)	800	1165	1218	1265
	Eq. (8)	760	1049	1156	1217
	Eq. (9)	760	1096	1170	1219
	Exp.	780 ± 13	1063 ± 8	1174 ± 10	

Reaction Cross Section for Halo Nuclei

Proron target (Carbon target)

One-neutron halo case $\Psi = \psi_C \phi(\boldsymbol{r})$

$$
\begin{aligned}
\mathrm{e}^{i\chi(\boldsymbol{b})} &= \langle\phi|\mathrm{e}^{i\chi_{CN}(\boldsymbol{b}-\frac{1}{A_C+1}\boldsymbol{s})+i\chi_{NN}(\boldsymbol{b}+\frac{A_C}{A_C+1}\boldsymbol{s})}|\phi\rangle \\
&= \langle\phi|[1-\Gamma_{CN}(\boldsymbol{b}-\tfrac{1}{A_C+1}\boldsymbol{s})][1-\Gamma_{NN}(\boldsymbol{b}+\tfrac{A_C}{A_C+1}\boldsymbol{s})]|\phi\rangle
\end{aligned}
$$



Two-neutron halo case

$$\Psi = \psi_C \phi(\boldsymbol{r}_1, \boldsymbol{r}_2)$$

$$\mathrm{e}^{i\chi(\boldsymbol{b})} = \langle \phi | \mathcal{O} | \phi \rangle$$

$$\mathcal{O} = [1 - \Gamma_{CN}(\boldsymbol{b} - \tfrac{2}{A_C+2}(\boldsymbol{s}_1 + \boldsymbol{s}_2))][1 - \Gamma_{NN}(\boldsymbol{b} + \tfrac{A_C+1}{A_C+2}\boldsymbol{s}_1 - \tfrac{1}{A_C+2}\boldsymbol{s}_2)]$$

$$\times[1 - \Gamma_{NN}(\boldsymbol{b} + \tfrac{A_C+1}{A_C+2}\boldsymbol{s}_2 - \tfrac{1}{A_C+2}\boldsymbol{s}_1)]$$

Suzuki,Lovas,Yabana,Varga, Structure and reactions of light exotic nuclei (Taylor and Francis)

Example: $^{22}C =^{20} C + n + n$

$$r^2(^{22}C) = \frac{10}{11} r^2(^{20}C) + \frac{10}{121}\langle(\frac{\boldsymbol{r}_1 + \boldsymbol{r}_2}{2})^2\rangle + \frac{1}{44}\langle(\boldsymbol{r}_1 - \boldsymbol{r}_2)^2\rangle$$

A preliminary calculation for ^{22}C with three-body model
(W. Horiuchi and Y. Suzuki)

- $d_{5/2}$ assumed to be fully occupied in ^{20}C
- Pauli constraint with realistic NN potential
- S_{2n} is reproduced
- $\sqrt{r^2(^{22}C)} = 3.7 - 3.8$ fm if $\sqrt{r^2(^{20}C)} \approx 3$ fm
- interesting to calculate $\sigma_{reac}(^{22}C)$

Very large radius !! *Very good candidate for S-wave halo*