Lunch seminar (June 16, 2010 at YITP)

Diffraction phenomena in nucleus-nucleus elastic scattering

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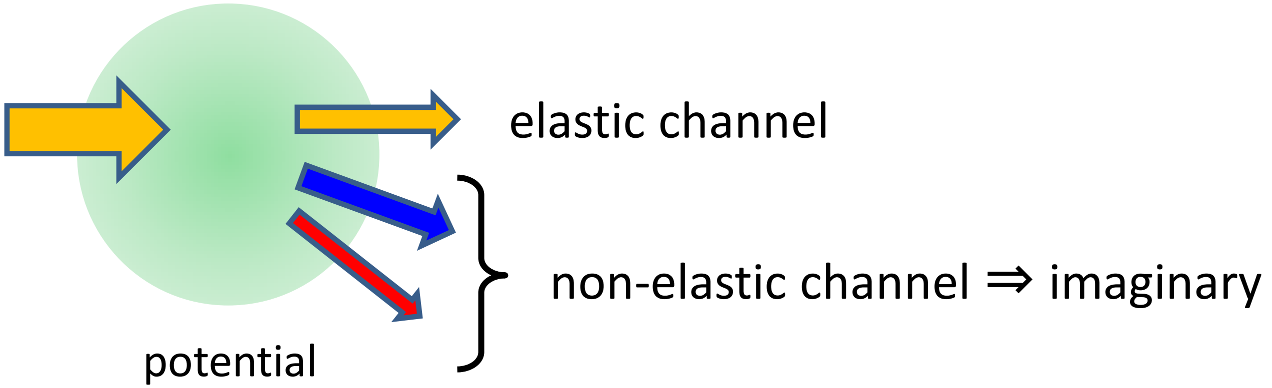
Introduction

- **Optical model potential (OMP)**

  - is complex potential

  - has the imaginary part that represents the loss of flux in elastic scattering

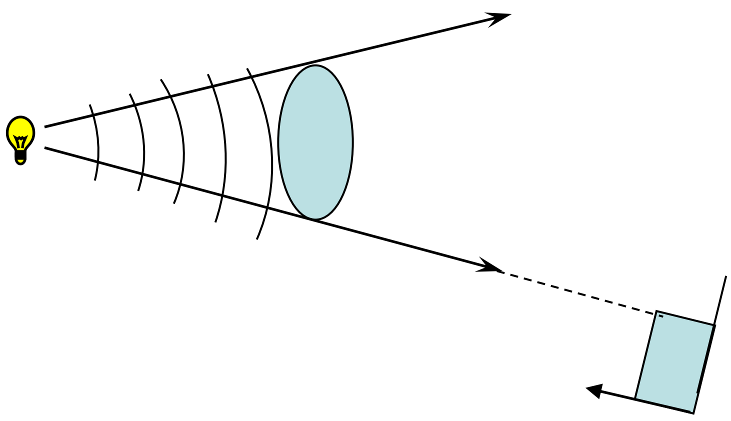


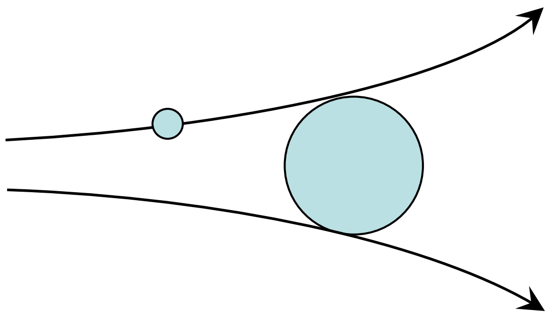
$$U_{opt}(r) = V(r) + iW(r)$$

1. Fresnel diffraction

1. illuminant near the wall ⇒ 『low energy heavy–ion scattering』

・strong absorption, ・strong Coulomb repulsion

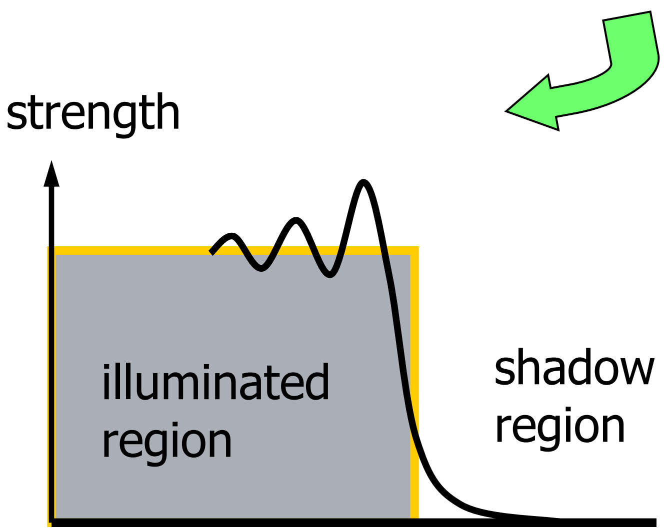


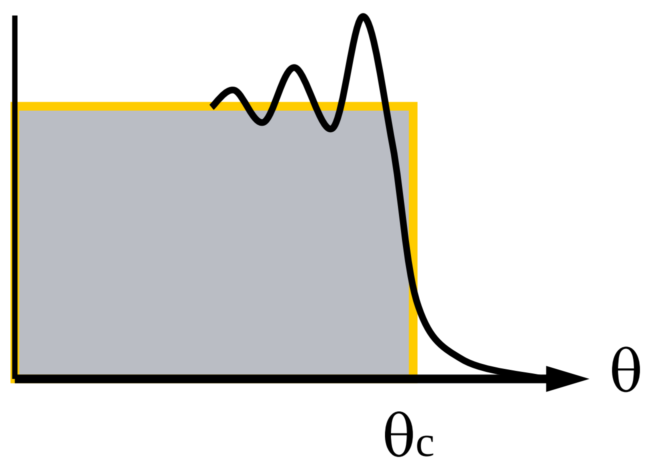


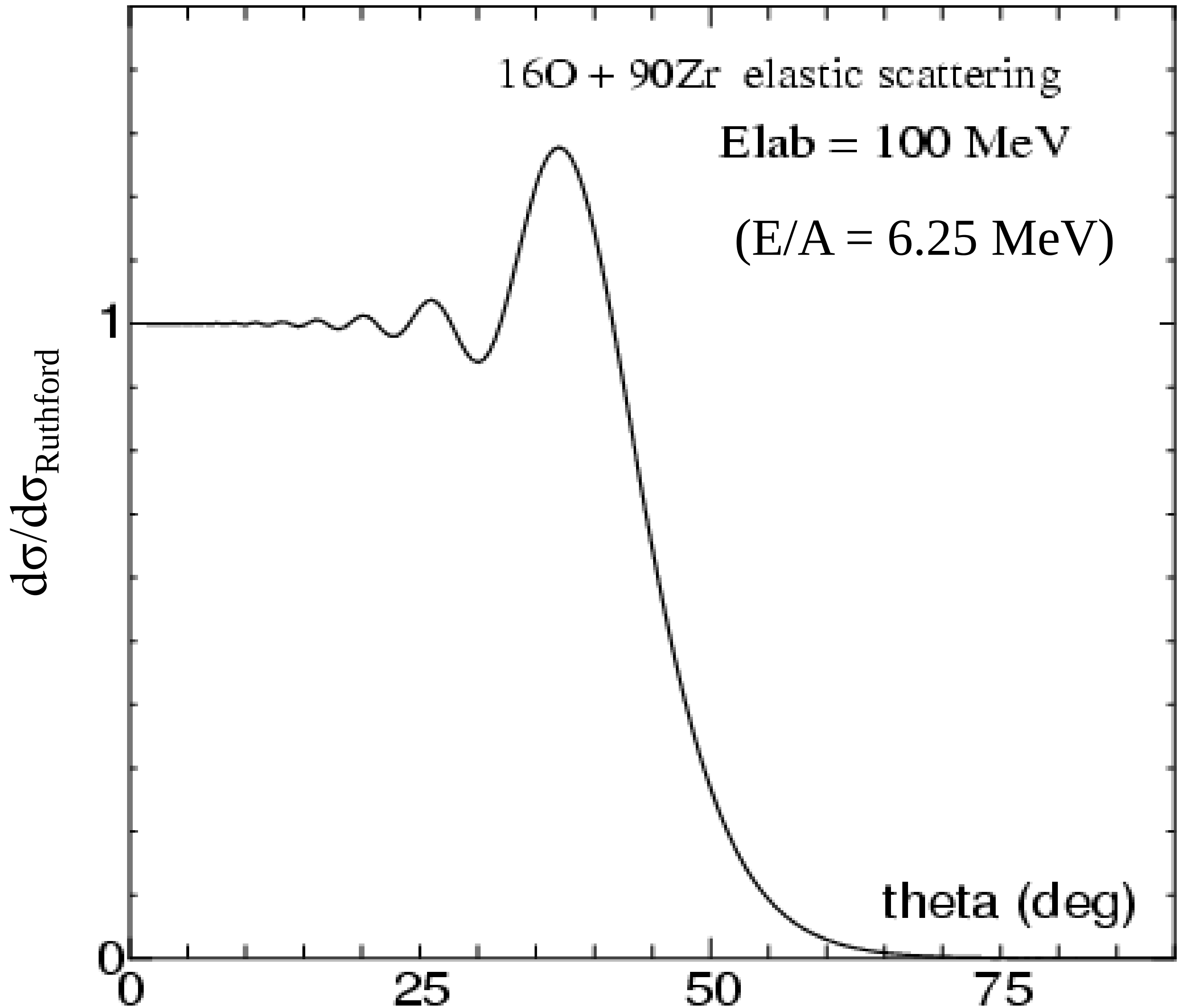
heavy ion scattering by heavy ion target at low energy

・strong absorption

・strong Coulomb repulsion






16O + 90Zr elastic scattering
Elab = 100 MeV
(E/A = 6.25 MeV)
dσ/dσRuthford
1
0
0
25
50
75
theta (deg)

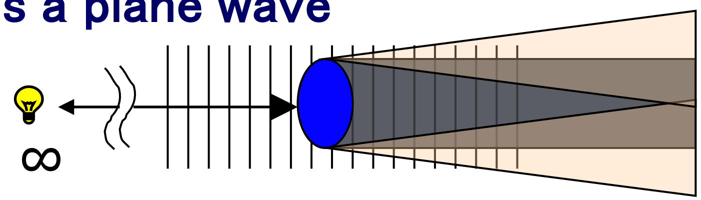
2. Fraunhofer diffraction

『high energy light−ion scattering』

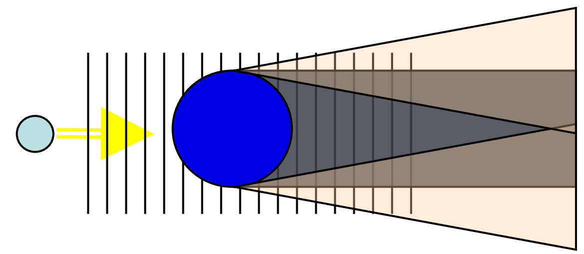
⇔ weak Coulomb repulsion

- illuminant from infinity to the slit

a ray of light incident (incident wave) is a plane wave

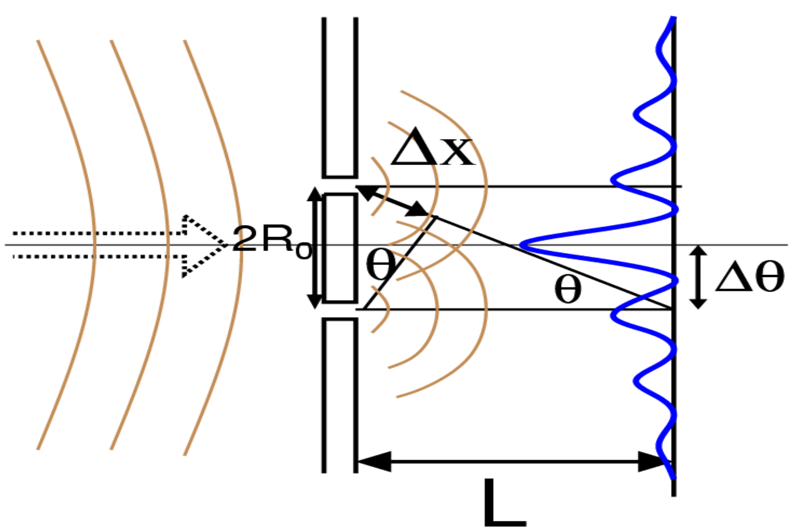


edge-waves



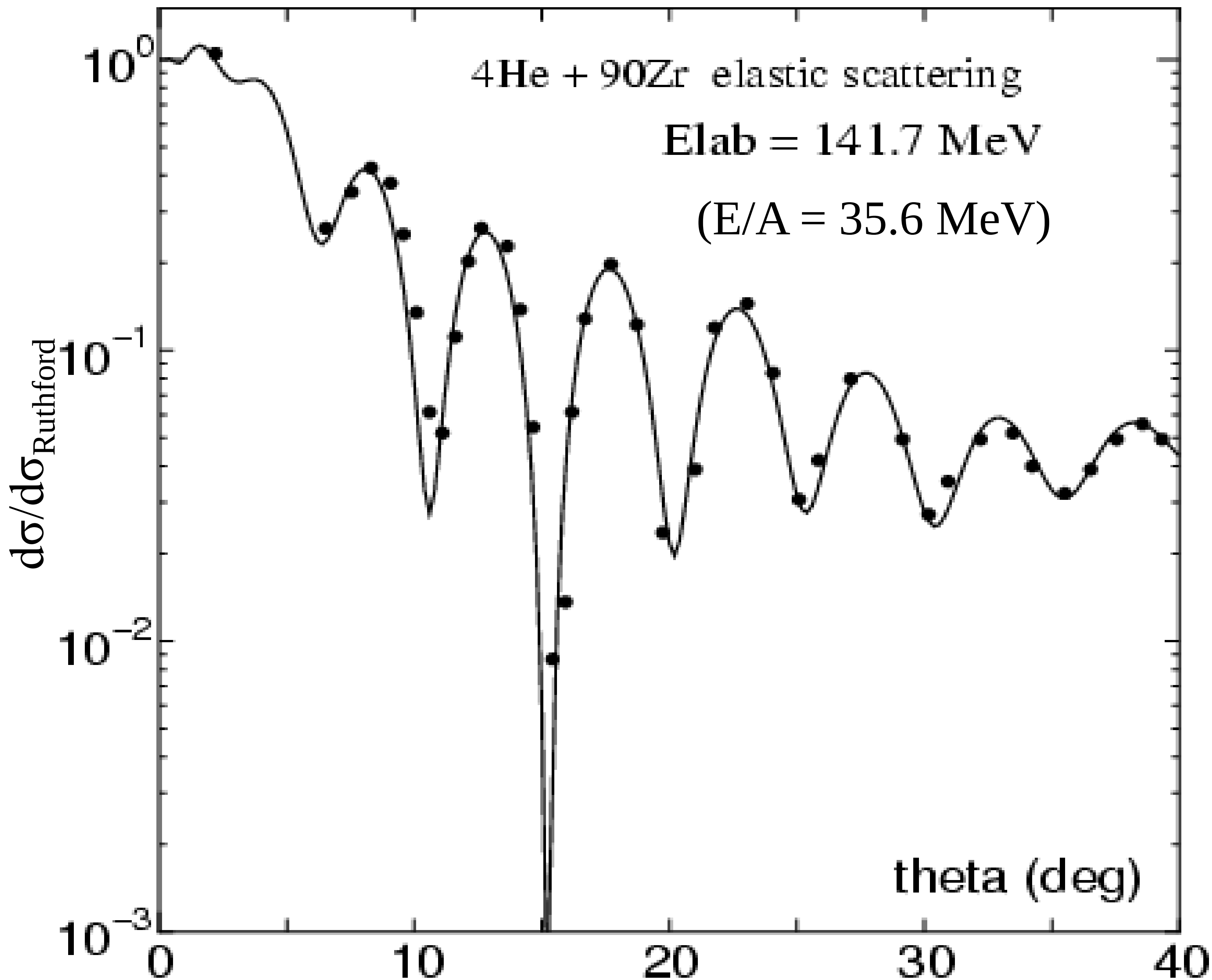
edge-waves

Young 2 slits

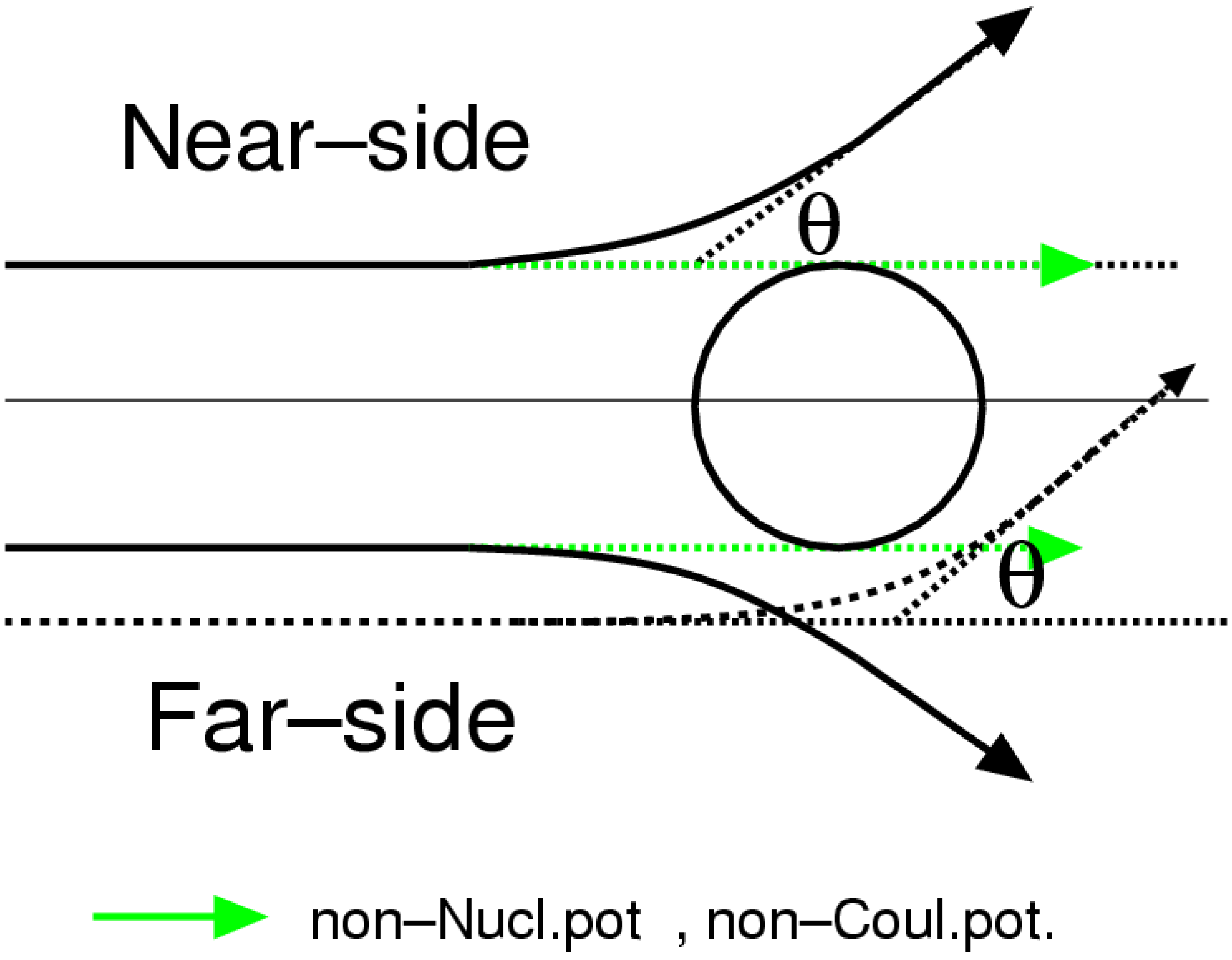


$$\lambda_D = 2R_0(\sin\theta_2 - \sin\theta_1)$$
$$\fallingdotseq 2R0(\theta 2 - \theta 1)$$
$$= 2R_0\,\Delta\theta$$

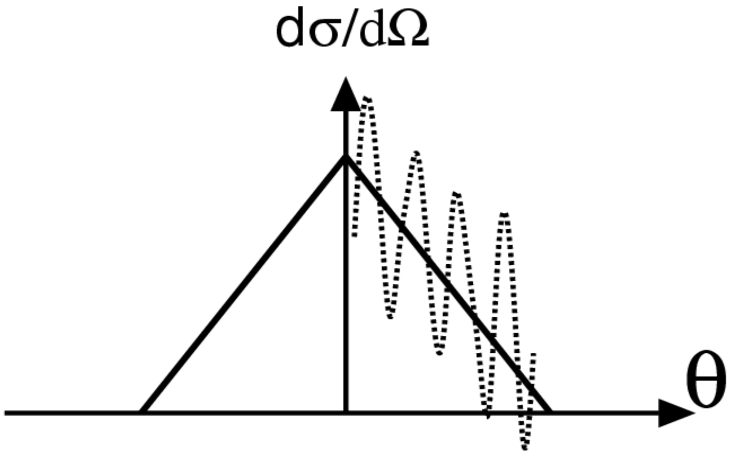
$$\Delta\theta = \lambda_D / 2R_0 = \pi / kR_0$$
$$= \pi / L_{gr}$$


4He + 90Zr elastic scattering
Elab = 141.7 MeV
(E/A = 35.6 MeV)
$d\sigma/d\sigma_{Ruthford}$
theta (deg)
10^{0}
10^{-1}
10^{-2}
10^{-3}
0
10
20
30
40

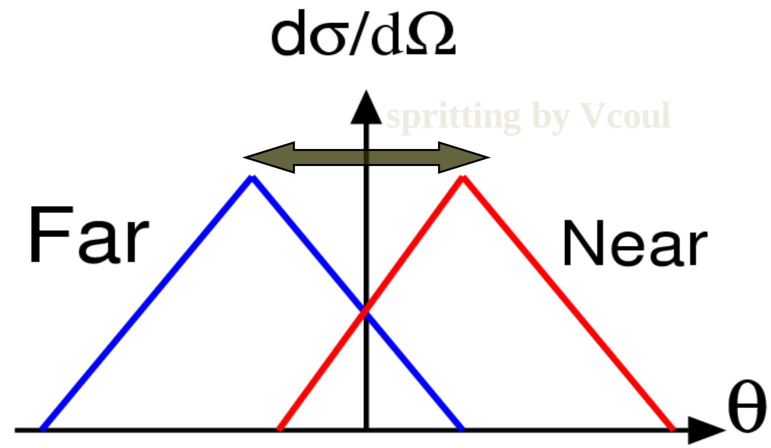
◇ Nearside-Farside decomposition



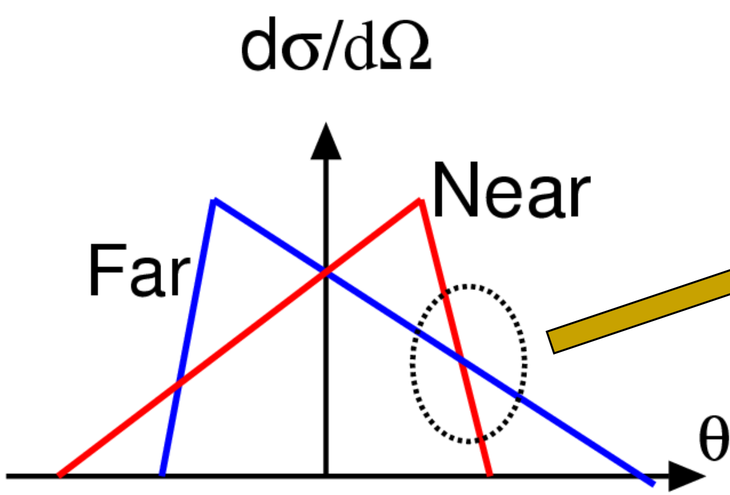
1. Vcoul = 0, Vnucl (real) = 0

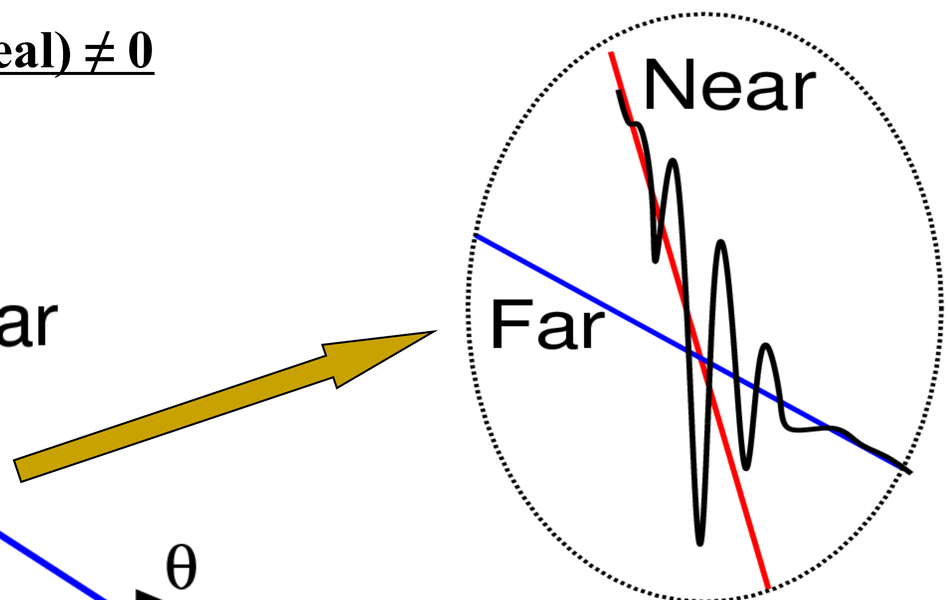


2. Vcoul ≠ 0, Vnucl (real) = 0



3. Vcoul ≠ 0, Vnucl (real) ≠ 0





• Nearside-Farside decomposition of the scattering amplitude

- R.C.Fuller, Phys.Rev.C12,1561(1975),
- K.W.McVoy, G.R.Satchler, Nucl.Phys. A417, 157 (1984)
- D.Brink, "Semi-classical methods for nucleus-nucleus scattering" (Cambridge Univ. Press, 1985)

$$f^{(nucl.)}(\theta) = \frac{i}{2k}\sum_{\ell=0}^{\infty}(2\ell+1)e^{2i\sigma_\ell}(1-S_\ell)P_\ell(\cos\theta),$$

$$P_\ell(\cos\theta) = \tilde{Q}_\ell^{(+)}(\cos\theta) + \tilde{Q}_\ell^{(-)}(\cos\theta)$$

$$\tilde{Q}_\ell^{(\pm)}(\cos\theta) = \frac{1}{2}\left[P_\ell(\cos\theta) \mp iQ_\ell(\cos\theta)\right]$$

$$= f_N(\theta) + f_F(\theta), \ (Q_\ell(\cos\theta): \text{Legendre function of second kind})$$

$$f_N^{(nucl.)}(\theta) \equiv \frac{i}{2k}\sum_{\ell=0}^{\infty}(2\ell+1)e^{2i\sigma_\ell}(1-S_\ell)\tilde{Q}_\ell^{(+)}(\cos\theta): \text{Nearside amplitude}$$

$$f_F^{(nucl.)}(\theta) \equiv \frac{i}{2k}\sum_{\ell=0}^{\infty}(2\ell+1)e^{2i\sigma_\ell}(1-S_\ell)\tilde{Q}_\ell^{(-)}(\cos\theta): \text{Farside amplitude}$$

$$\left|f^{(nucl.)}(\theta)\right|^2 = \left|f_N^{(nucl.)}(\theta)\right|^2 + \left|f_F^{(nucl.)}(\theta)\right|^2 + 2\,\mathrm{Re}\left(f_N^{*(nucl.)}(\theta)\, f_F^{(nucl.)}(\theta)\right)$$

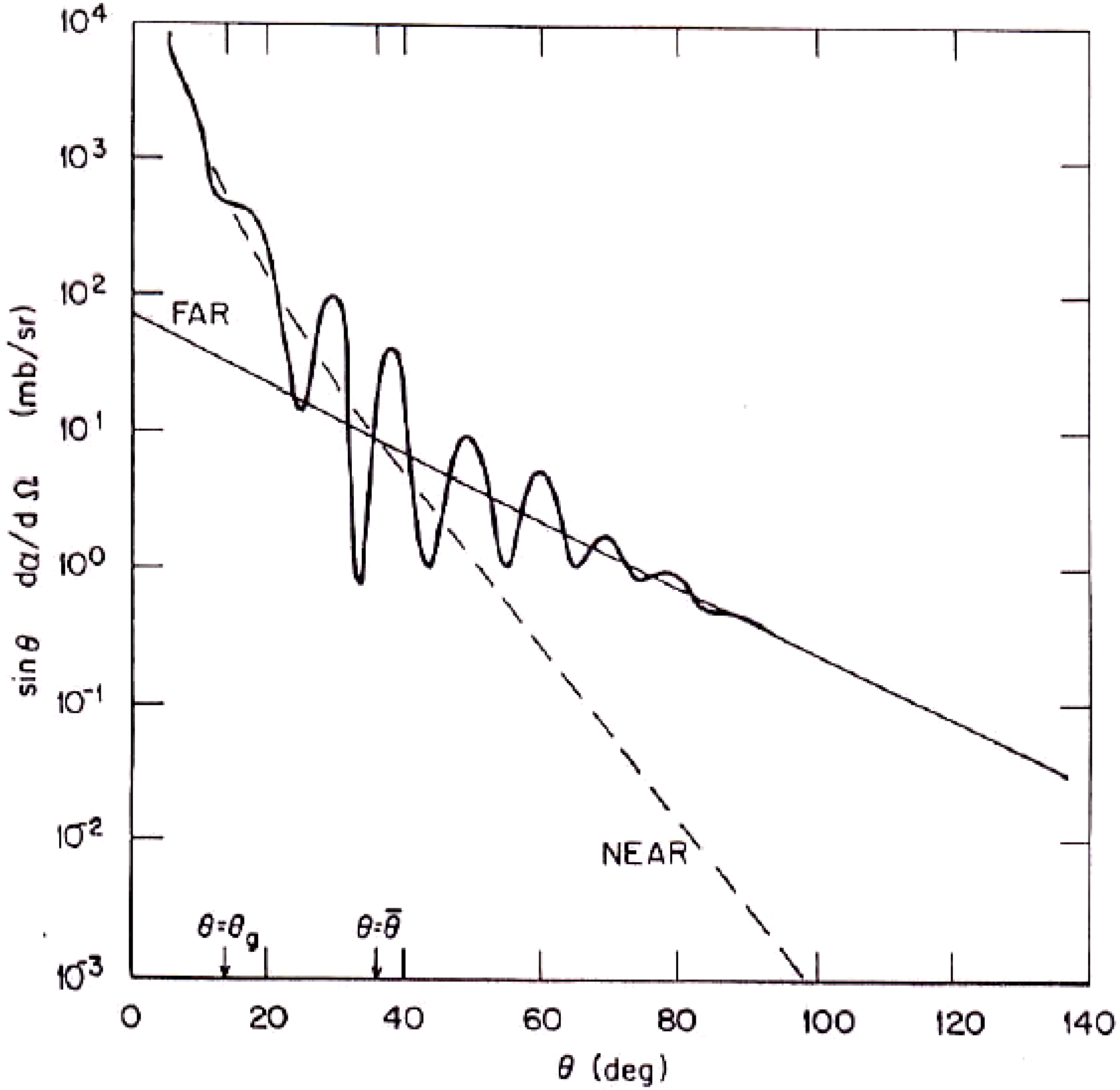
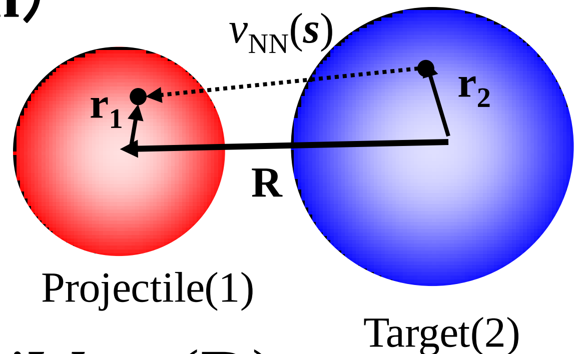


FIG. 11.17. Far-side/near-side decomposition for a case ($n = 2.15$, $\Lambda = 17.5$, $\Delta = 0.86$, $\alpha = 1.3$) corresponding to $\alpha + {}^{44}\text{Ti}$ at 42 MeV. The dashed curve is the cross section due to the near-side amplitude $f^{(+)}(\theta)$ alone, the solid straight line is due to the far-side amplitude $f^{(-)}(\theta)$ alone, and the oscillatory solid curve is due to their coherent sum. The two terms are equal at $\bar{\theta} \simeq 36°$. (After Rowley and Marty 1976.)

Formalism
(microscopic approach)

Folding model potential

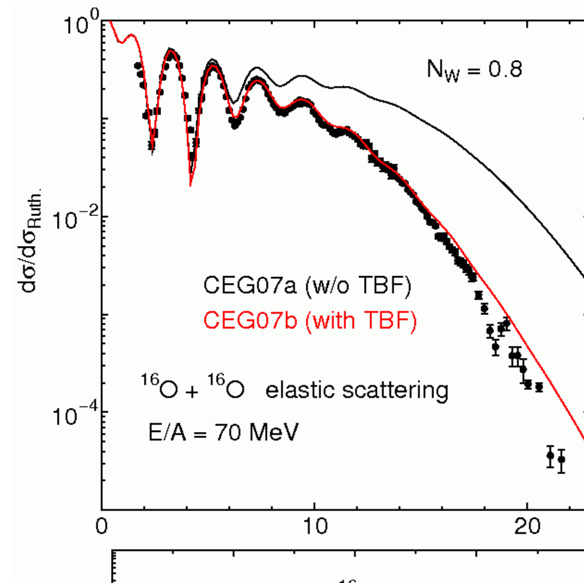


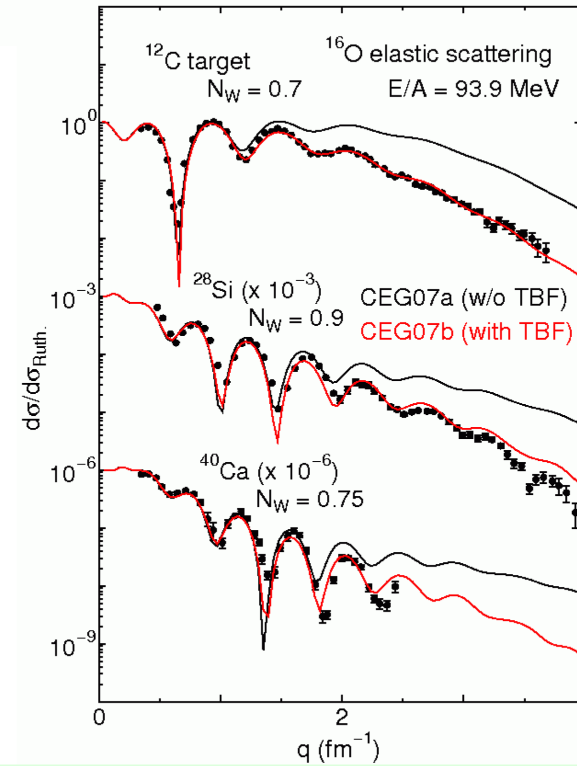
$$U(\mathbf{R}) = V_{DFM}(\mathbf{R}) + iW_{DFM}(\mathbf{R})$$
$$= \int \rho_1(\mathbf{r}_1)\rho_2(\mathbf{r}_2) \underline{v_{NN}(\mathbf{s}; \rho, E)} d\mathbf{r}_1 d\mathbf{r}_2$$

Interaction
CEG07 (complex G-matrix interaction)

CEG07a (w/o TBF)

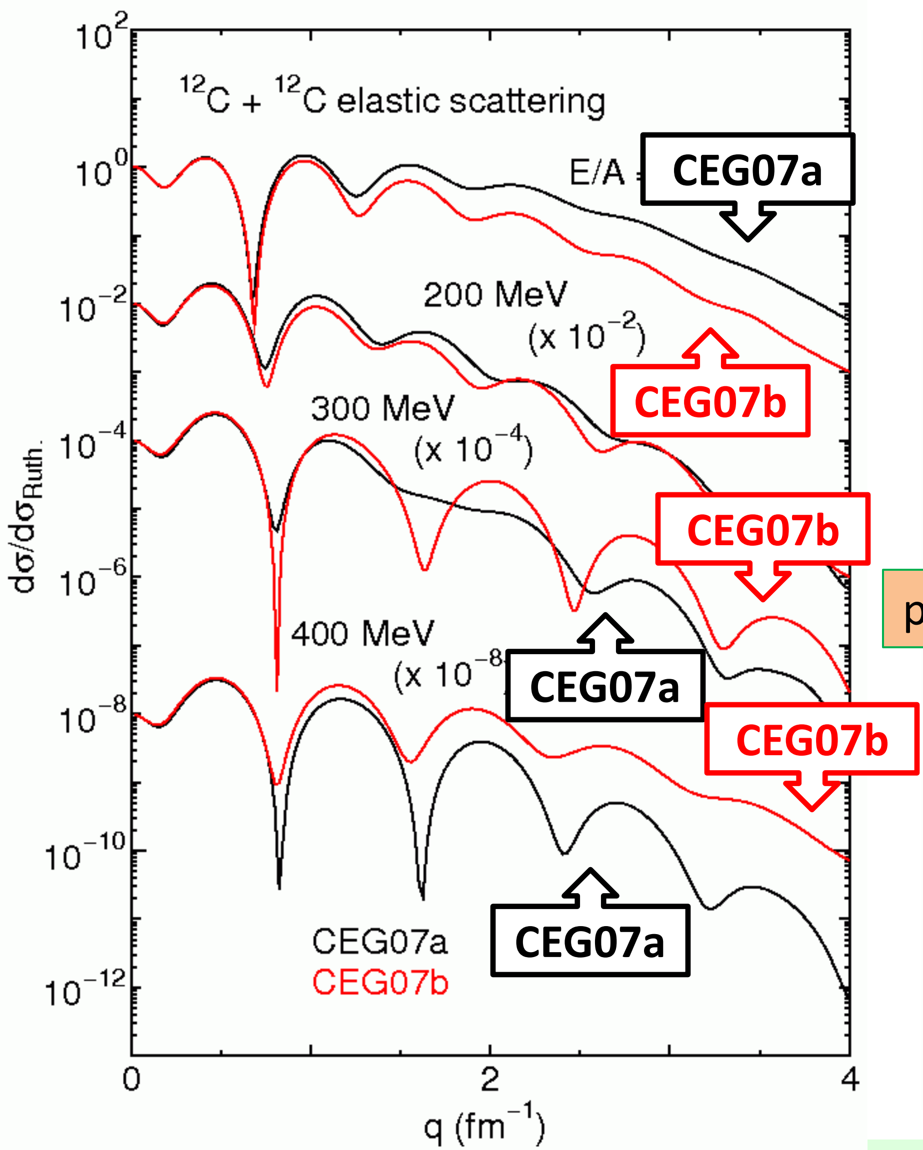
CEG07b (with TBF)

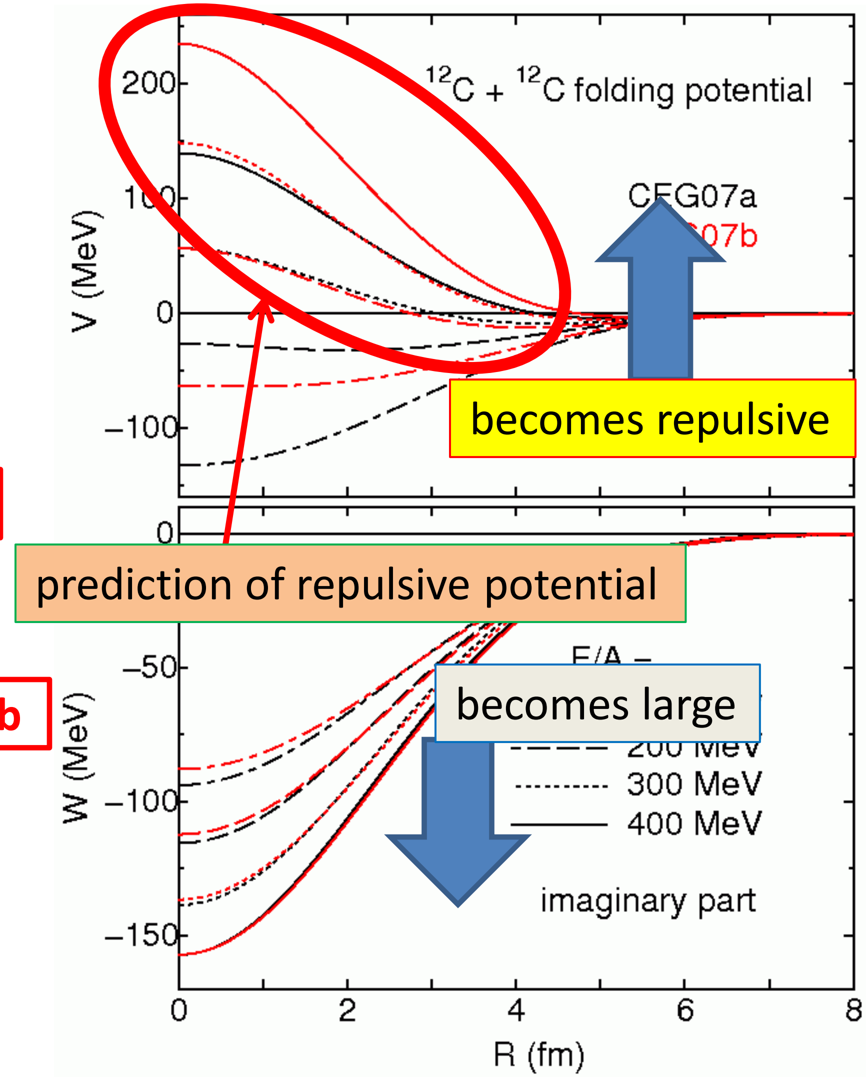




T.F., Y. Sakuragi and Y. Yamamoto, (Phys. Rev. C.79 (2009) 011601(R))
T.F., Y. Sakuragi and Y. Yamamoto, (Phys. Rev. C.80 (2009) 044614)

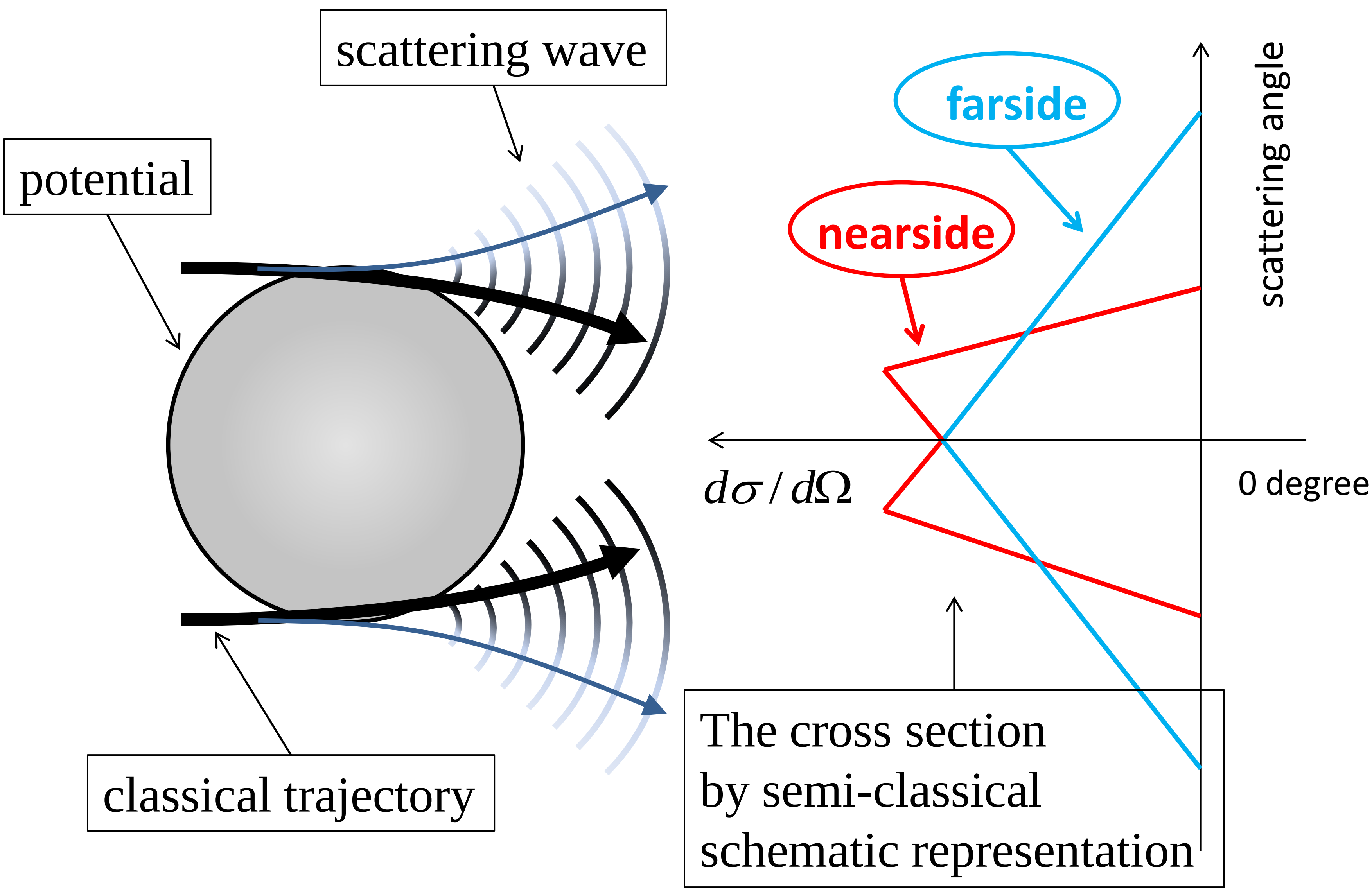
^{12}C + ^{12}C elastic scattering at various energies



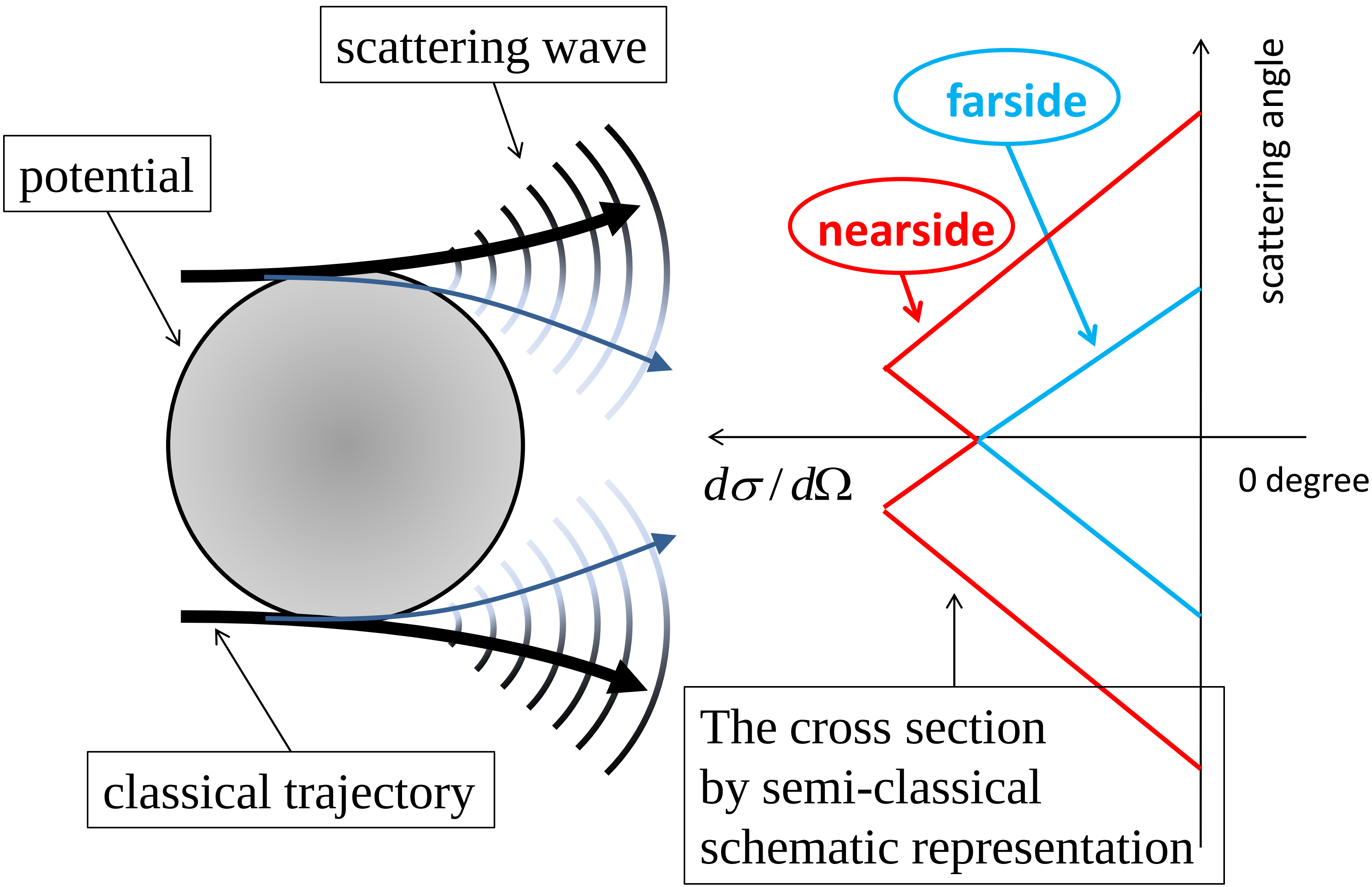


T.F., Y. Sakuragi and Y. Yamamoto, Phys. Rev. C, to appear

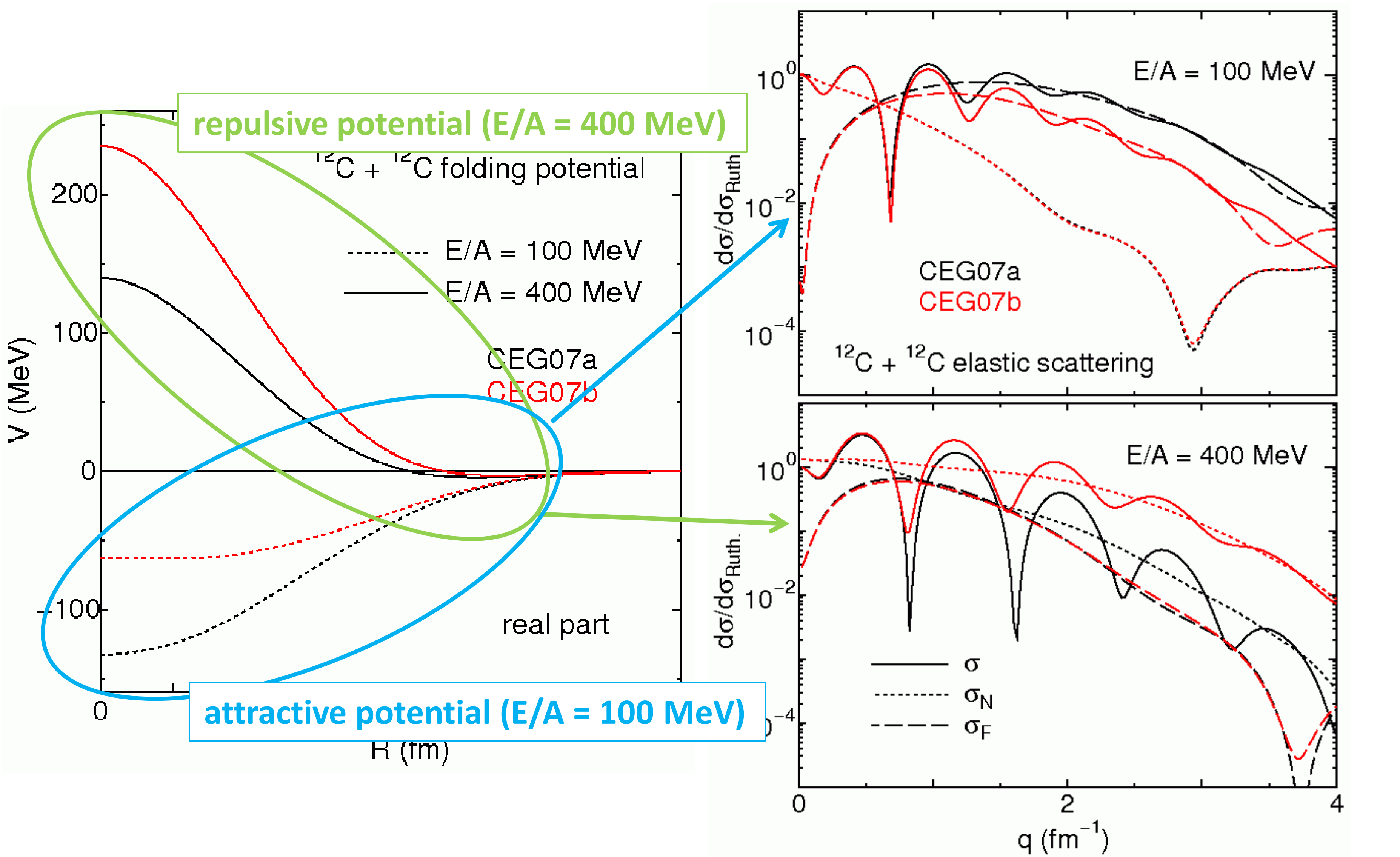
(a) Attractive potential (V < 0)



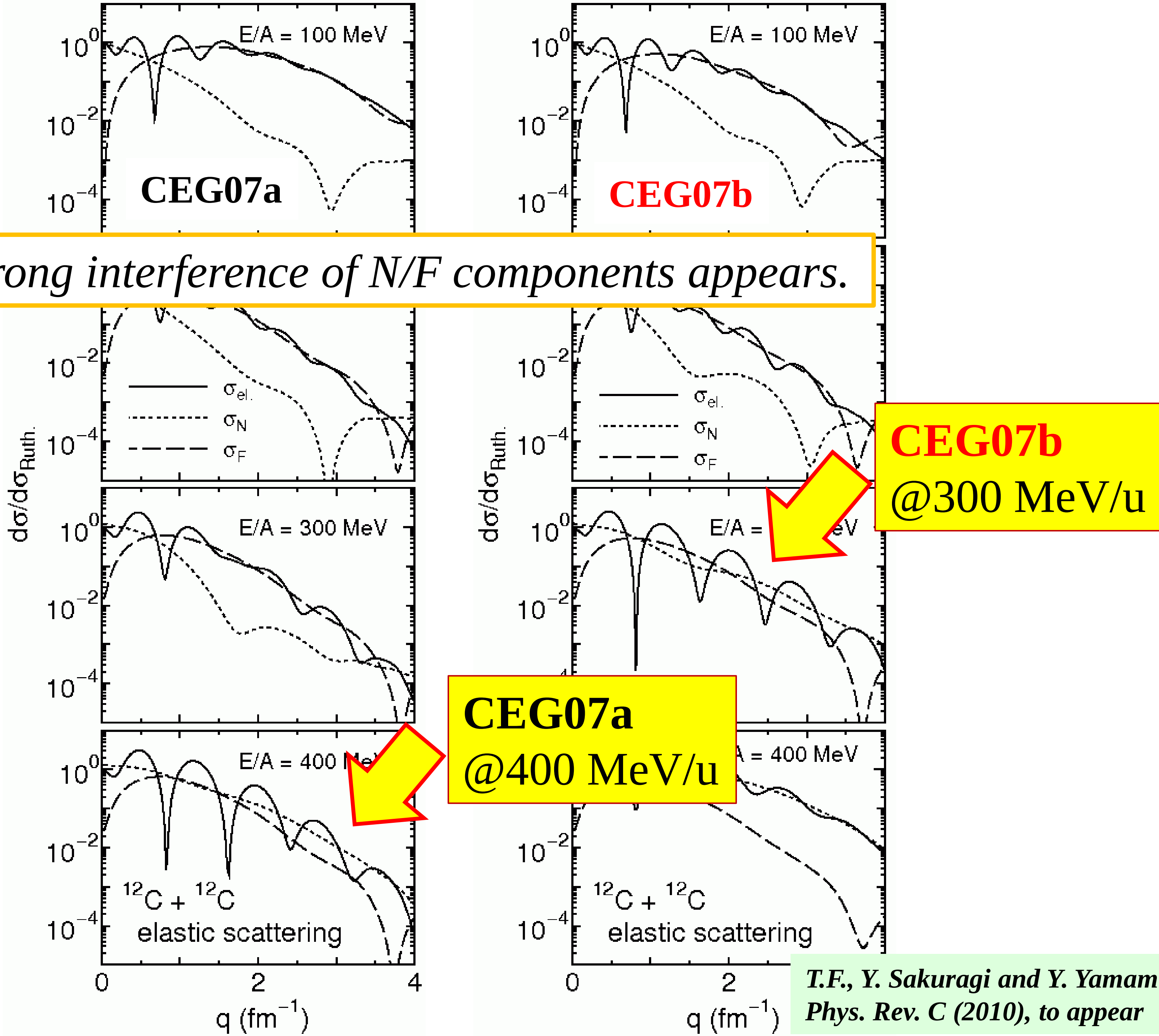
(b) Repulsive potential (V > 0)



Nearside and farside (N/F) decomposition



T.F., Y. Sakuragi and Y. Yamamoto, Phys. Rev. C, to appear



The strong interference of N/F components appears.

T.F., Y. Sakuragi and Y. Yamamoto, Phys. Rev. C (2010), to appear

Summary

<u>**CEG07 folding model**</u> **predicts the repulsive nuclear potential at high energy region (E/A = 300 - 400 MeV).**

It is first survey that the repulsive nucleus-nucleus potential is derived from the microscopic view point.

<u>**Property of nuclear repulsive potential**</u>

- The nearside becomes large and the farside becomes small around backward angles <u>**by not Coulomb potential but nuclear potential**.</u>
- <u>**The strong interference**</u> appears at a certain energy by repulsive shift of nuclear potential in energy evolution.