The Galileo Galilei Institute for Theoretical Physics

Istituto Nazionale di Fisica Nucleare

A phenomenological optical potential for the n-^{12}C scattering

Post-Doc Day
GGI
16 December 2022

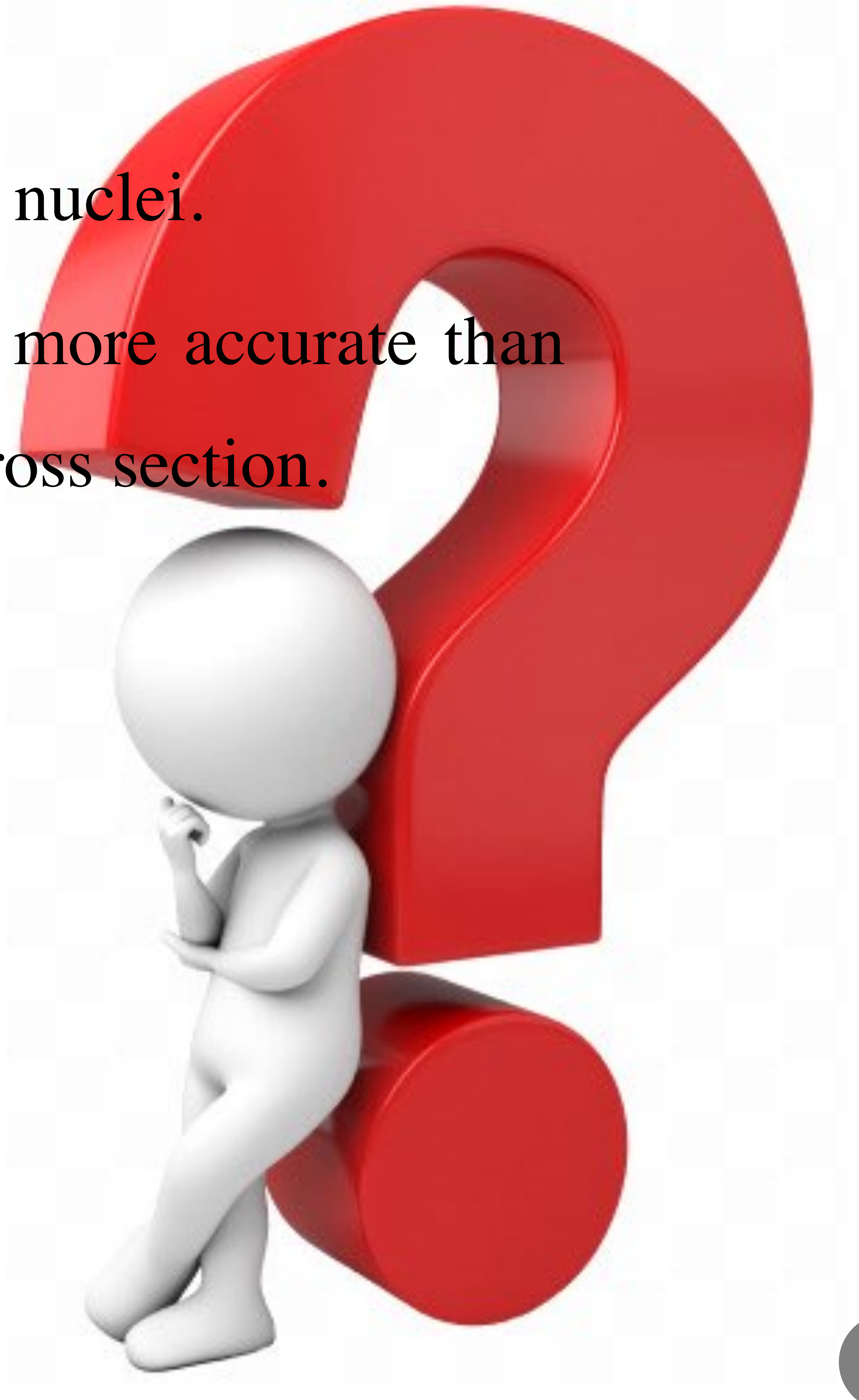
Imane MOUMENE
Under the supervison of: Prof. Angela Bonaccorso

Work Plan

- **Motivation**
- **Basic equations of the model:**
  - **1. Optical model potential for the n-^{12}C scattering**
  - **2.Nucleus-nucleus cross section**
- **Results**
  - **3.n-^{12}C total cross sections**
  - **4.nucleus-^{12}C reaction cross sections**
- **Perspective**
- **Conclusion**

Motivation

- Breakup reaction is one of the main tools for the study of exotic nuclei.
- The single-folded nucleus-^{9}Be imaginary optical potential is more accurate than the double-folded optical potential in reproducing the reaction cross section.
- Why ^{12}C ???
  - ☆ Most used target in the experiments.
  - ☆ Cluster physics (3 α cluster)
  - ☆ Astrophysics (^{12}C+^{12}C fusion)
  - ☆ Nuclear reaction
  - ☆……



In this work

- A phenomenological optical model potential for the n-^{12}C is introduced up to E=500 MeV.

- A comparison of calculated neutron-target total reaction cross sections with the eikonal formalism through the phenomenological potential versus folded potential.

- Comparison of calculated reaction cross sections of projectile on a ^{12}C target via a single folding versus a double folding optical potential.

Basic equations of the model

Optical model potential for the n-^{12}C scattering

- The n-^{12}C phenomenological (AB) potential :

$$U_{AB}(r,E) = -\left[V_{WS}(r,E) + \delta V(r,E) + iW_{AB}(r,E)\right]. \quad (1)$$

n-T real part: WS

The correction term

The imaginary part

$$W_{AB}(r) = W^{vol} f(r,R^I,a^I) - 4a^I W^{sur}\frac{d}{dr}f(r,R^I,a^I)$$

Fitting data

- Single folded n-^{12}C potential:

$$U_\rho^{nT}(\mathbf{r}) = -\frac{1}{2}\hbar v(\sigma_{nn} - i\alpha_{nn})\rho_T(\mathbf{r}) \quad (2)$$

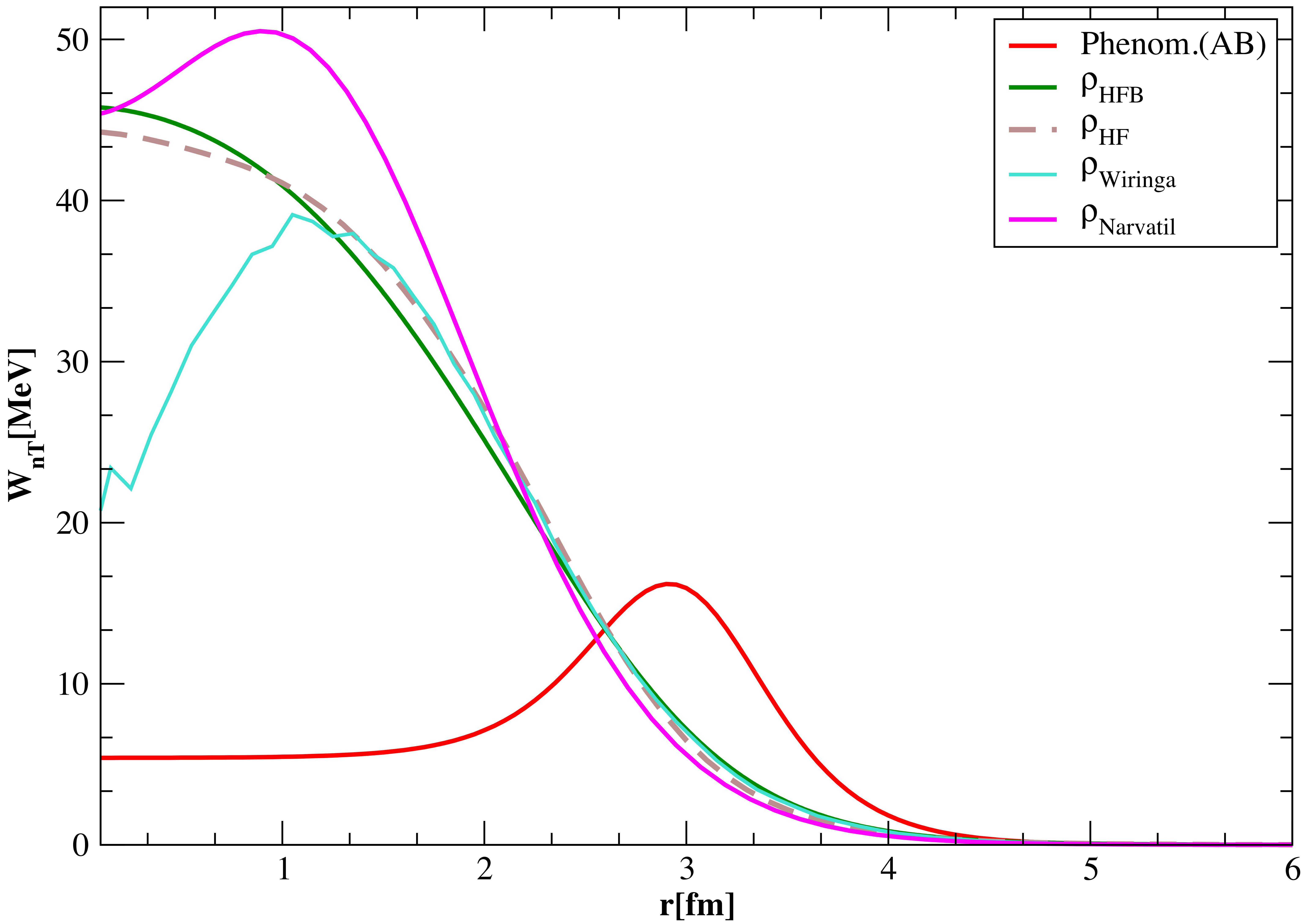
Energy-dependent nucleon-nucleon (nn) cross section

Target Density: HFB

- C.A. Bertulani, C. De Conti, Phys. Rev. C 81 (2010) 064603.
- Abu-Ibrahim, et al.PHYSICAL REVIEW C **77**, 034607 (2008)

Basic equations of the model

Optical model potential for the n-^{12}C scattering



E=300 MeV

Phenom.(AB) → Eq.(1)

ρ_i → Eq.(2)

Basic equations of the model

The nucleus-nucleus scattering

- The eikonal reaction cross section:

$$\sigma_R = 2\pi \int_0^\infty bdb \left(1 - \left|S_{PT}(\mathbf{b})\right|^2\right) \quad (3)$$

Where

$$\left|S_{PT}(\mathbf{b})\right|^2 = e^{2\chi_I(b)} \quad (4)$$

- The imaginary part of the eikonal phase shift:

$$\chi_I(\mathbf{b}) = \frac{1}{\hbar v} \int dz W^{PT}(\mathbf{b}, z) \quad (5)$$

Single folding potential:

$$W^{PT}_{s.f.}(\mathbf{r}) = \int d\mathbf{b_1} W^{nT}\left(\mathbf{b_1} - \mathbf{b}, z\right) \int dz_1 \rho_P\left(\mathbf{b_1}, z_1\right) \quad (5.1)$$

n+^{12}C phenomenological nucleon-target potential (AB) (Eq.(1))

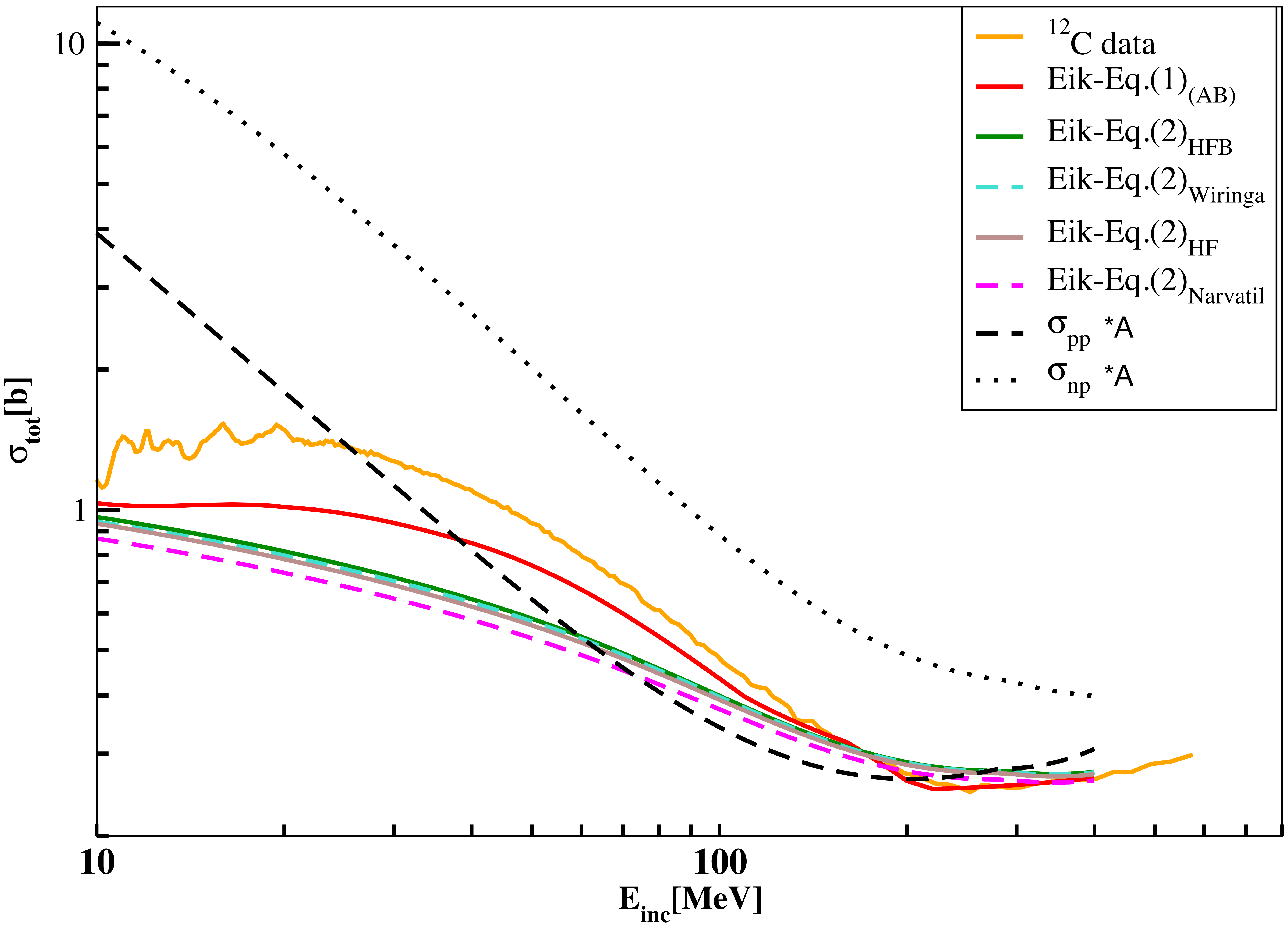
Double folding potential:

$$W^{PT}_{d.f.}(\mathbf{r}) = -\frac{1}{2}\hbar v \sigma_{nn} \int d\mathbf{b}_1 \rho_T\left(\mathbf{b}_1 - \mathbf{b}, z\right) \int dz_1 \rho_P\left(\mathbf{b}_1, z_1\right) \quad (5.2)$$

Densities: HFB code

- G.R. Satchler, W.G. Love, Phys. Rep. 55 (1979) 183.

Results: n-^{12}C total cross section



Results: n-^{12}C total cross section

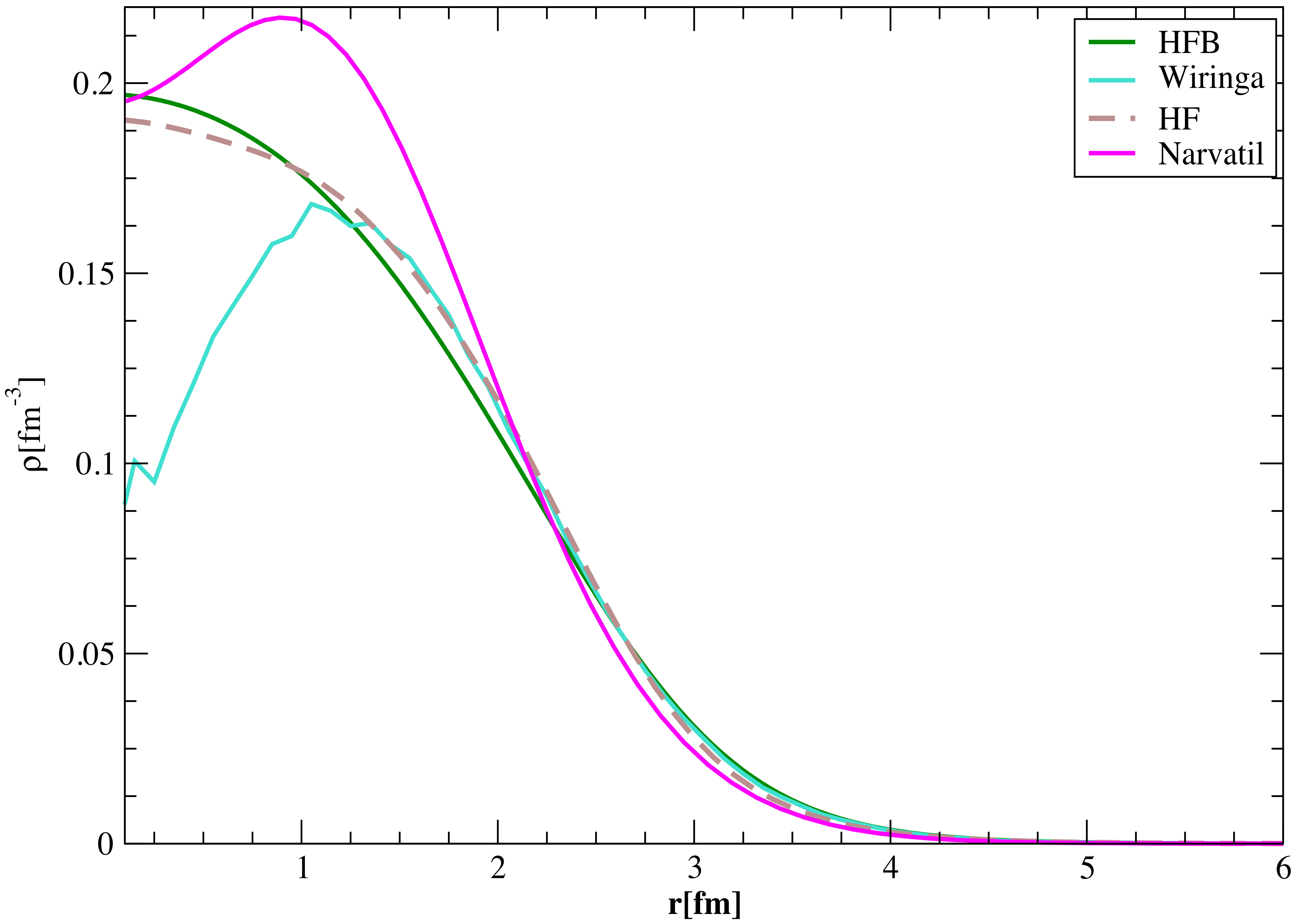
E=300 MeV

Densitties	HFB	HF	Wiringa	Narvatil
$\sigma^{\rho}_{s.f.}[mb]$ (Eq.(2))	273	270	273	262
$\sigma^{AB}_{s.f.}[mb]$ (Eq.(1))	257			
$\sigma_{exp}[mb]$	254			

Results: n-^{12}C total cross section

- **Target Densities**

E=300 MeV



Results: nucleus-^{12}C cross section

- **The $^{12}C + ^{12}C$ scattering**

E_{inc}(MeV)	model	r_s[fm]	σ_{theo} [mb]	σ_{exp} [mb]
200	s.f.	1.20	947	864
	d.f.	1.11	847	
250	s.f.	1.18	935	873
	d.f.	1.11	835	
300	s.f	1.18	936	858
	d.f.	1.11	832	

Results: nucleus-^{12}C cross section

- **The $^{12}C + ^{12}C$ scattering**

r=1.2

E_{inc}(MeV)	model	r_s[fm]	σ_{theo} [mb]	σ_{exp} [mb]
200	s.f.	1.13	858	864
	d.f.	1.11	847	
250	s.f.	1.11	846	873
	d.f.	1.11	835	
300	s.f	1.11	848	858
	d.f.	1.11	832	

Strong absorption radius

The strong absorption radius:

$$|S_{PT}(R_S)|^2 = \frac{1}{2} \qquad \textbf{(7)}$$

With

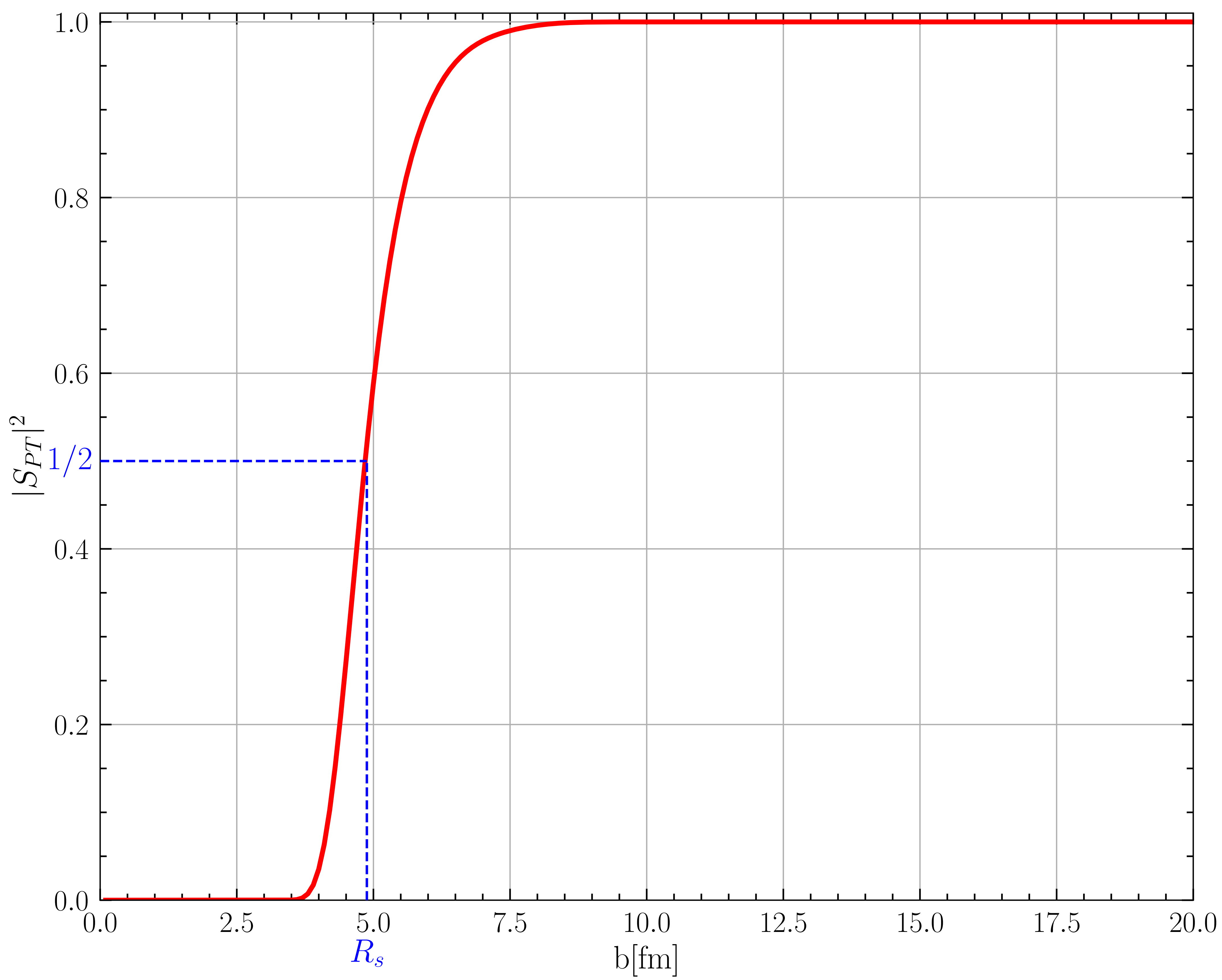
$$R_s = r_s(E_{inc})\left(A_P^{1/3} + A_T^{1/3}\right) \qquad \textbf{(8)}$$

r_s : Determine the range of impact parameters for which surface reacti dominate the core-target interaction from regions in which the stro absorption regime applies.

Reminder:

$$\sigma_R = 2\pi \int_0^\infty bdb \left(1 - \left|S_{PT}(\mathbf{b})\right|^2\right)$$

$$\left|S_{PT}(\mathbf{b})\right|^2 = e^{2\chi_I(b)}$$



Results: nucleus-^{12}C cross section

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

E_{inc}(MeV)	model	r_s[fm]	σ_{theo} [mb]	σ_{exp} [mb]
100	s.f.	1.27	1327	1161
	d.f.	1.21	1206	
200	s.f.	1.21	1193	1123
	d.f.	1.15	1079	
300	s.f.	1.21	1181	1168
	d.f.	1.13	1062	

Conclusion

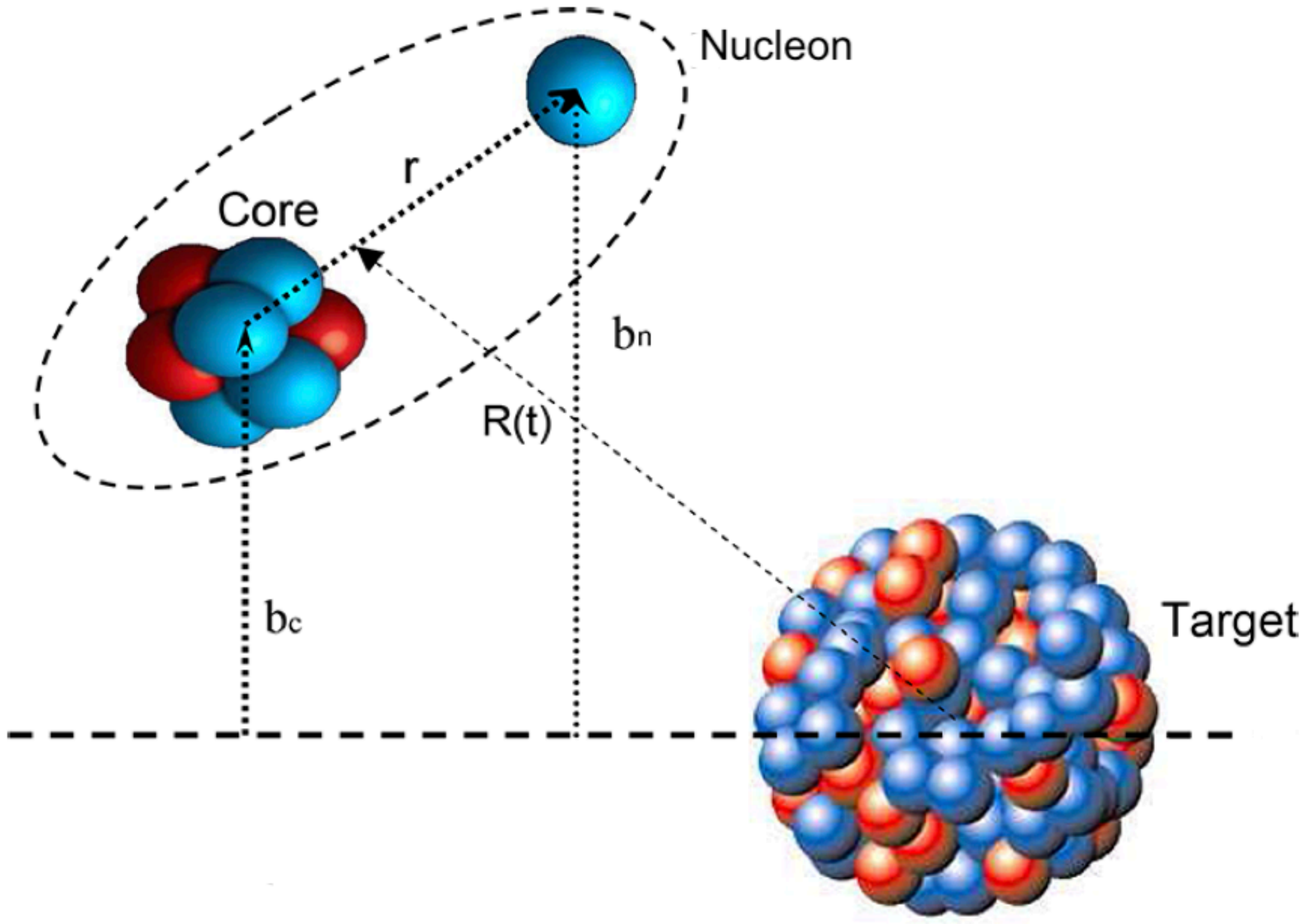
- The constructed phenomenological optical potential for the n- ^{12}C scattering provides an excellent reproduction of the total cross sections.
- At higher energies, the double folding model is more reliable than the single folding model in describing the reaction cross sections for nucleus-nucleus scattering.

The optical potential for n- ^{12}C is necessary in breakup models to calculate the S-matrices for the core-target and nucleon target scattering.

Perspective: Breakup reactions

■ Breakup is a dissociation of the projectile into two or more fragments caused by the interaction with the target nucleus.

a+A ⟶ b+x+A



■ **Exclusive breakup:** The breakup particle is measured in coincidence with the core origin

■ **Inclusive Breakup**: Only the core is measured

a+A ⟶ b+B* (B* any possible configuration of x+A)

Elastic Breakup reaction (EBU)

Inelastic breakup reaction (NEB)

Perspective: Breakup reactions

- **The Breakup reaction cross sections:**

$$\sigma_{\text{reac}} = \sigma_{\text{EBU}} + \sigma_{\text{NEB}}$$

- **Elastic Breakup (Diffraction)**

$$\sigma_{EBU} = \int \mathrm{d}^2\mathbf{b}_c \left| S_{ct}\left(\mathbf{b}_c\right) \right|^2 \int \mathrm{d}^2\mathbf{r}_\perp \left| 1 - S_n\left(\mathbf{b}_n\right) \right|^2 \left| \tilde{\phi}_0\left(\mathbf{r}_\perp\right) \right|^2$$

- **Non Elastic Breakup (Stripping)**

$$\sigma_{NEB} = \int \mathrm{d}^2\mathbf{b}_c \left| S_{ct}\left(\mathbf{b}_c\right) \right|^2 \int \mathrm{d}^2\mathbf{r}_\perp \left(1 - \left| S_n\left(\mathbf{b}_n\right) \right|^2 \right) \left| \tilde{\phi}_0\left(\mathbf{r}_\perp\right) \right|^2$$

Thank you for your attention