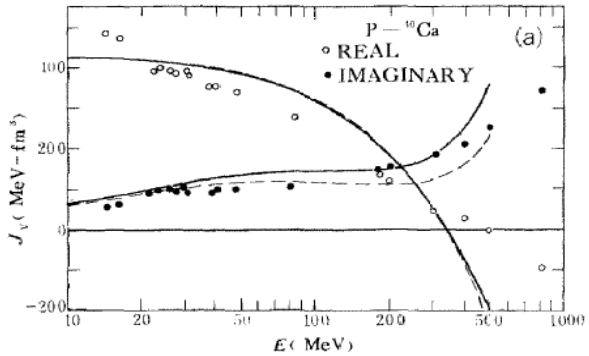
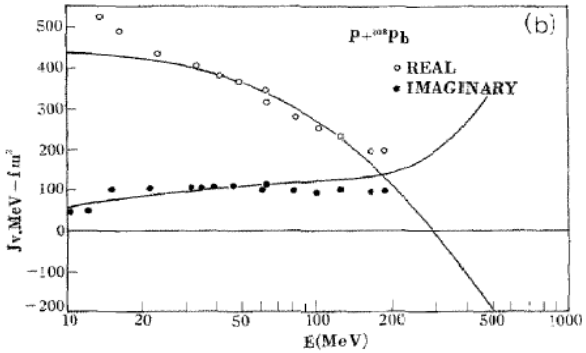
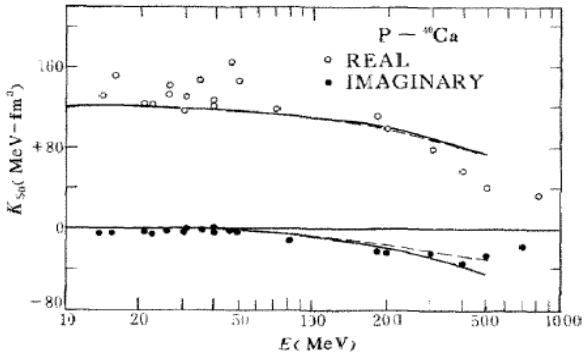
Microscopic Optical Potential in Relativistic Approach

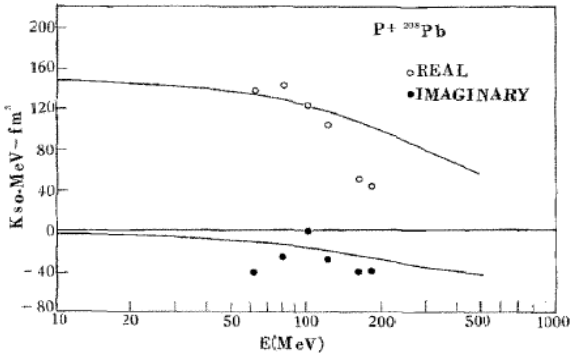
Zhongyu Ma

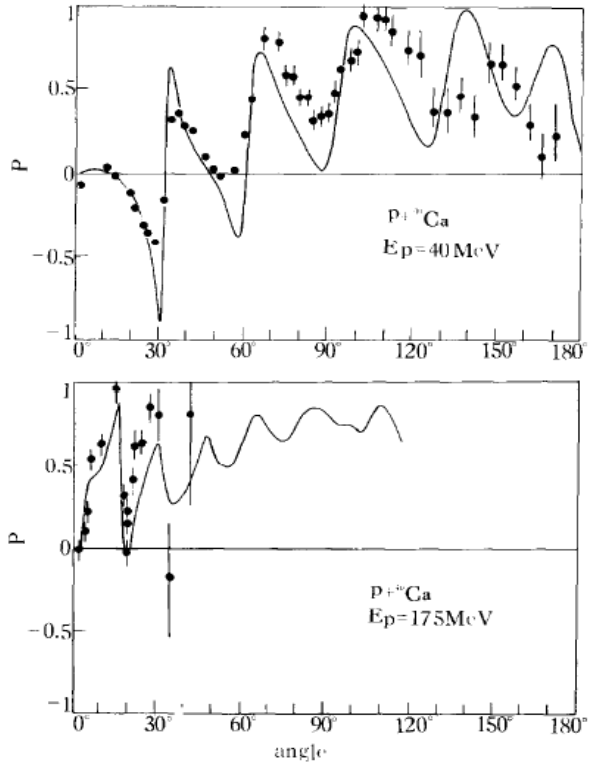
Microscopic Optical Model Potentials











Volume integrals

Analyzing power

Ma , Zhu, Gu, Zhuo, Nulc. Phys. A490(88)619

Introduction

- Current interests of OMP:

  The dependence of N-A, A-A scattering potentials (OMP) on

  ρ, k (or E), $\beta=(\rho_n - \rho_p)/\rho$

  Extension to high densities, energies and isospin dependence

- Two levels of approaches in studying the microscopic OMP
  - Phenomenological nuclear effective int

    Skyrme force, M3Y(DDM3Y),

    RMF based on isoscalar meson exchanges
  - Microscopic approaches from bare NN interactions

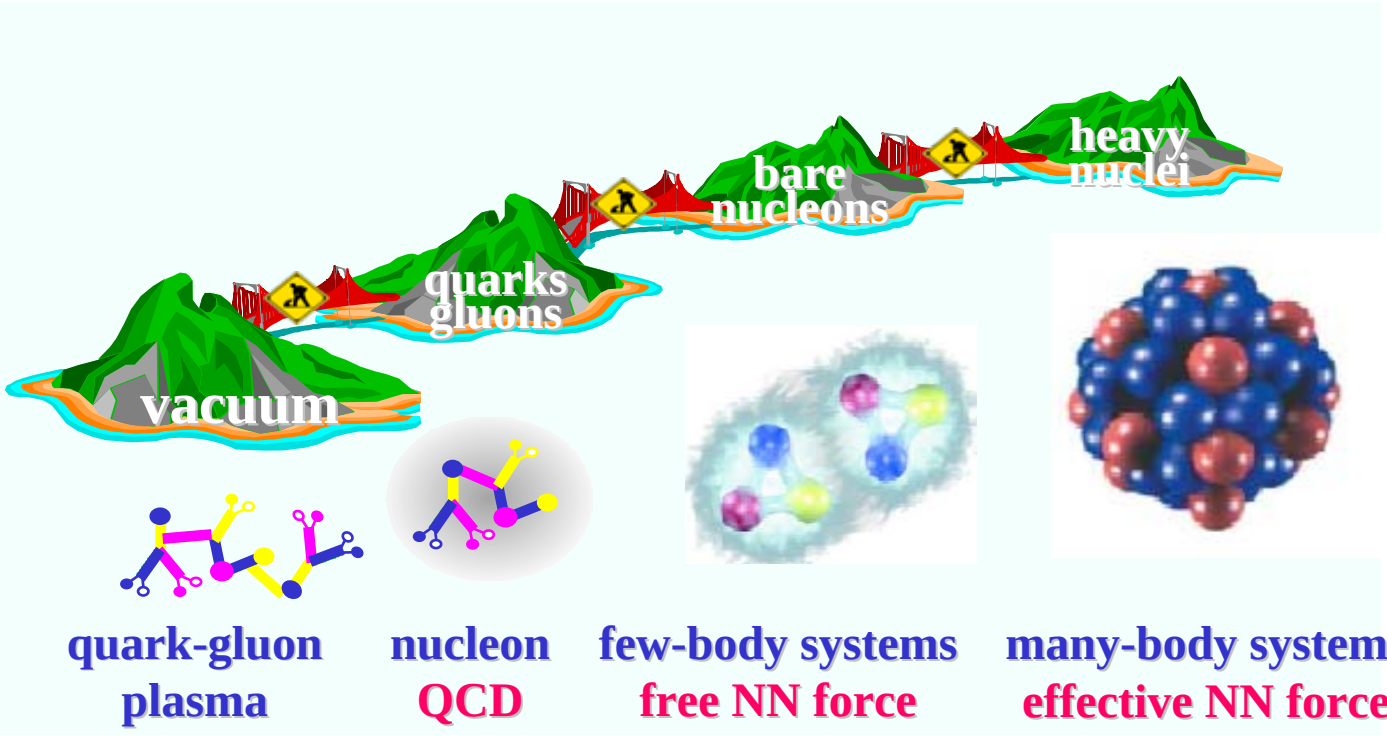
    BHF DBHF

IOP Publishing Journal of Physics G: Nuclear and Particle Physics

J. Phys. G: Nucl. Part. Phys. 37 (2010) 060301 (2pp) doi:10.1088/0954-3899/37/6/060301

Open Problems in Nuclear Structure Theory

From simplicity to Complexity



Open Problem in Nuclear Structure Theory

IOP PUBLISHING JOURNAL OF PHYSICS G: NUCLEAR AND PARTICLE PHYSICS

J. Phys. G: Nucl. Part. Phys. 37 (2010) 064043 (10pp) doi:10.1088/0954-3899/37/6/064043

The Dirac–Brueckner–Hartree–Fock approach: from infinite matter to effective Lagrangians for finite systems

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Microscopic calculations of OMP

- Non relativistic approaches

BHF with bare NN int. can not apply to high densities

saturations are not well reproduced

J.-P.Jeukenne, A.Lejeune,C.Mahaux, PRC16(77)80

(JLM model)

BHF with bare NN + 3body int.

Real + Imaginary OMP at asymmetric NM

Li, Lombardo, Schulze, Zuo PRC77(08)034316

Li, Li, Zhao EG, Zhou SG, Zuo W, PRC80(09)064607

Spin-orbit interactions are put by hand

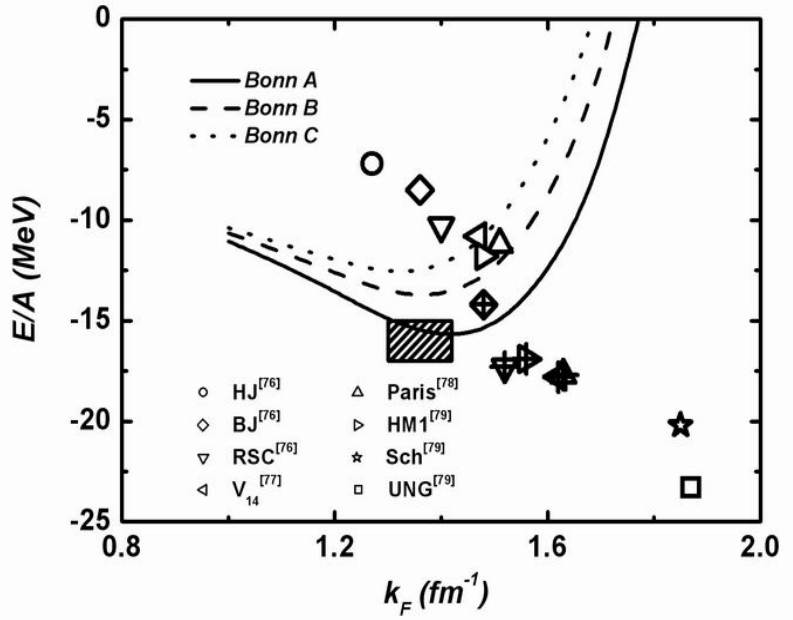
DBHF approach

- Relativistic approaches

  NN + DBHF

  Success in description of

  NM saturation properties



- OMP of nucleon in the nuclear matter is equivalent to the self energy of nucleon

  Finite nuclei: LDA

  $\Sigma(k,k_F,\beta)$ dep. → $\Sigma(E,r)$ dep.

  spin-orbit pot's are obtained naturally

Self-consistency DBHF

- Three dimension reduction -- the relativistic Thompson equation

$$T(\mathbf{p},\mathbf{q},x)|_{\text{c.m.}} = V(\mathbf{p},\mathbf{q}) + \int \frac{d^3\mathbf{k}}{(2\pi)^3} V(\mathbf{p},\mathbf{k}) \frac{m_{\text{F}}^{*2}}{E^{*2}(\mathbf{k})} \frac{Q(\mathbf{k},x)}{2E^*(\mathbf{q}) - 2E^*(\mathbf{k}) + i\epsilon} T(\mathbf{k},\mathbf{q},x)$$

the time-like component of the momentum transfer in *V* and *T* is set equal to zero

- Self-consistent calculations is important

T ~~→~~ ? Σ → Dirac eq. → s.p. wf

T matrix --- do not keep the track of rel. structure

Extract the nucleon self-energy with single particle energy

$$\varepsilon_i(k) = \sqrt{k^2 + [M + U_s^i(k)]^2} - U_0^i(k)$$ weak momentum dep.

$$\Sigma(k) \approx \Sigma(|k| = k_F) \longrightarrow \varepsilon_i(k) = \sqrt{k^2 + [M + U_s^i]^2} - U_0^i$$

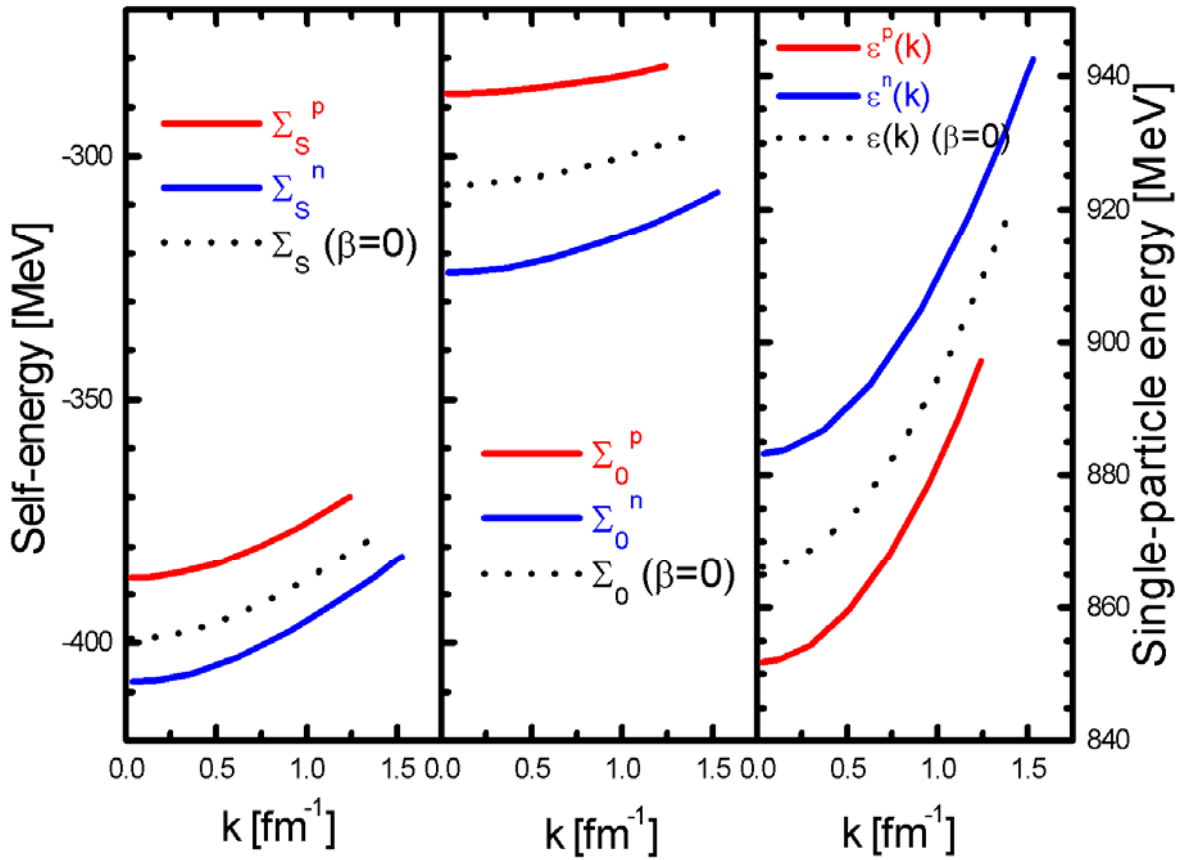
Difficulties in asymmetric NM

Us, Uo have different behavior of E dep. in asymmetric NM

$$\varepsilon_i(k) = \sqrt{k^2 + [M + U_s^i]^2} - U_0^i$$

This simple assumption fails in asymmetric nuclear matter

Wrong behavior of Isospin dependence of self-energies In asymmetric NM



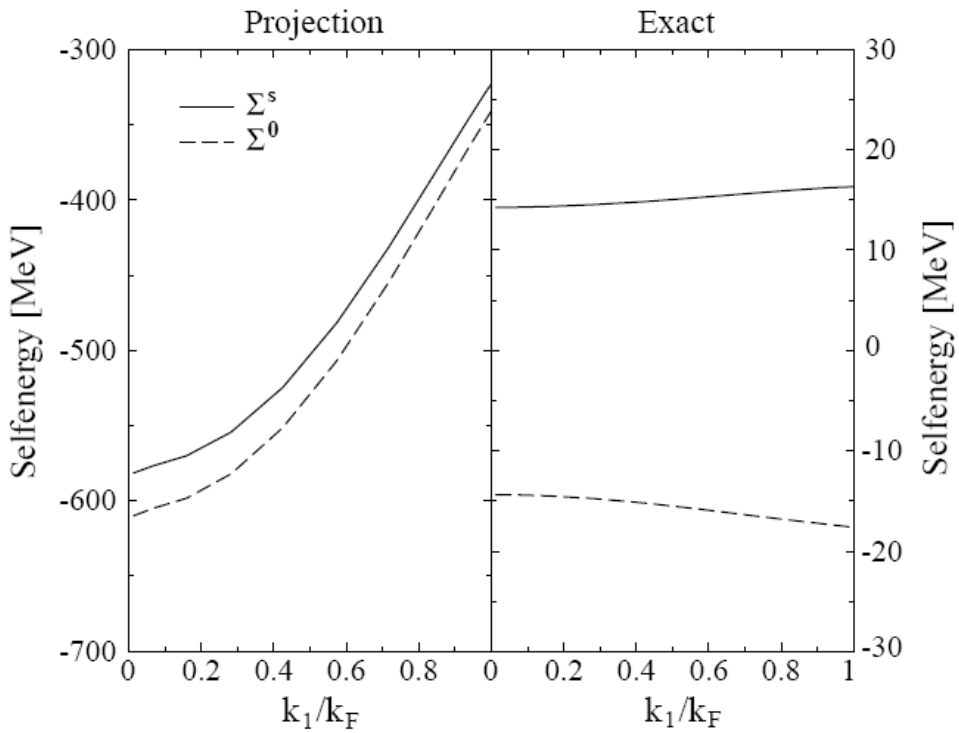
Isospin dependence of OMP

- Projection methods

$$T \rightarrow \left\{1, \gamma^{\mu}, \sigma^{\mu\nu}, \gamma^{5}\gamma^{\mu}, \gamma^{5}\right\}$$

Due to the restriction to positive energy states

Give a unphysical strong momentum dependence in the self-energy



originate mainly from the one-pion exchange contribution to the self-energy

Decomposition of T

- Decomposition of DBHF T matrix

$$T = V + \Delta T$$

V : OBEP σ ω η δ ρ π

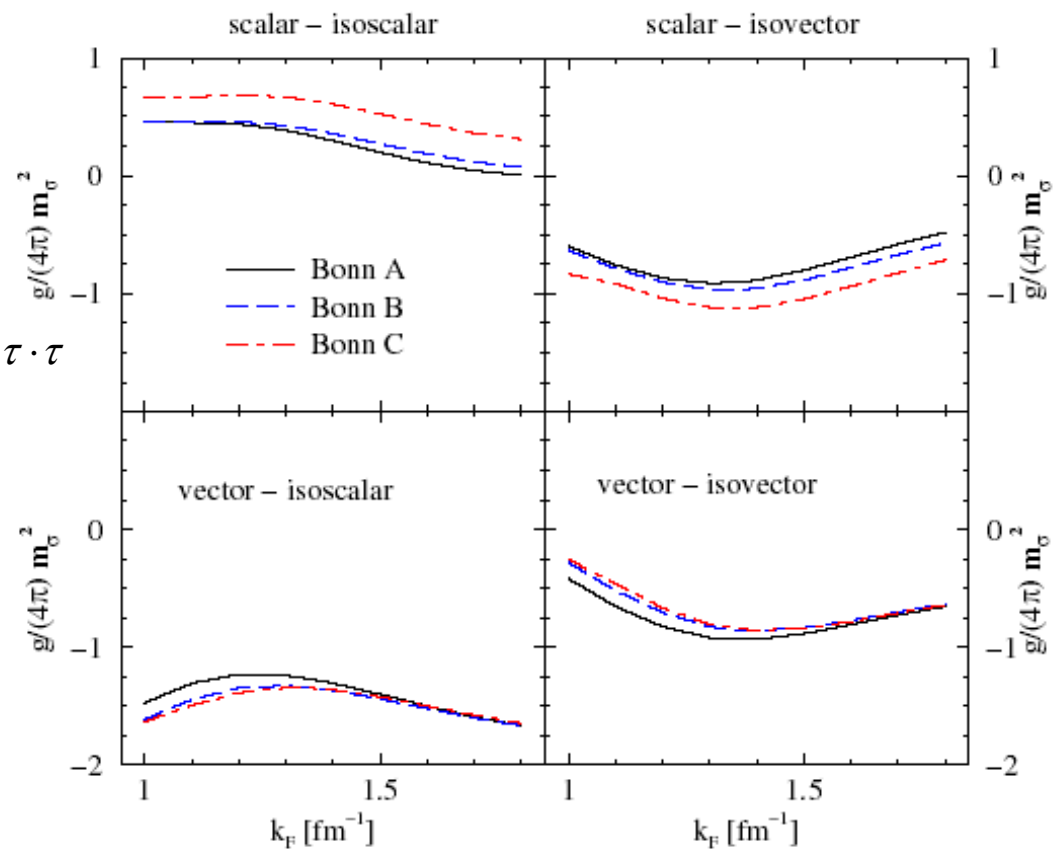
ΔT a projection method

$$\Delta T = \left[g_{s,s} 11 + g_{v,s} \gamma^{\mu} \gamma_{\mu} \right] + \left[g_{s,v} 11 + g_{v,v} \gamma^{\mu} \gamma_{\mu} \right] \tau \cdot \tau$$

$(1, \gamma_\mu)$ $(1, \tau)$

Short range

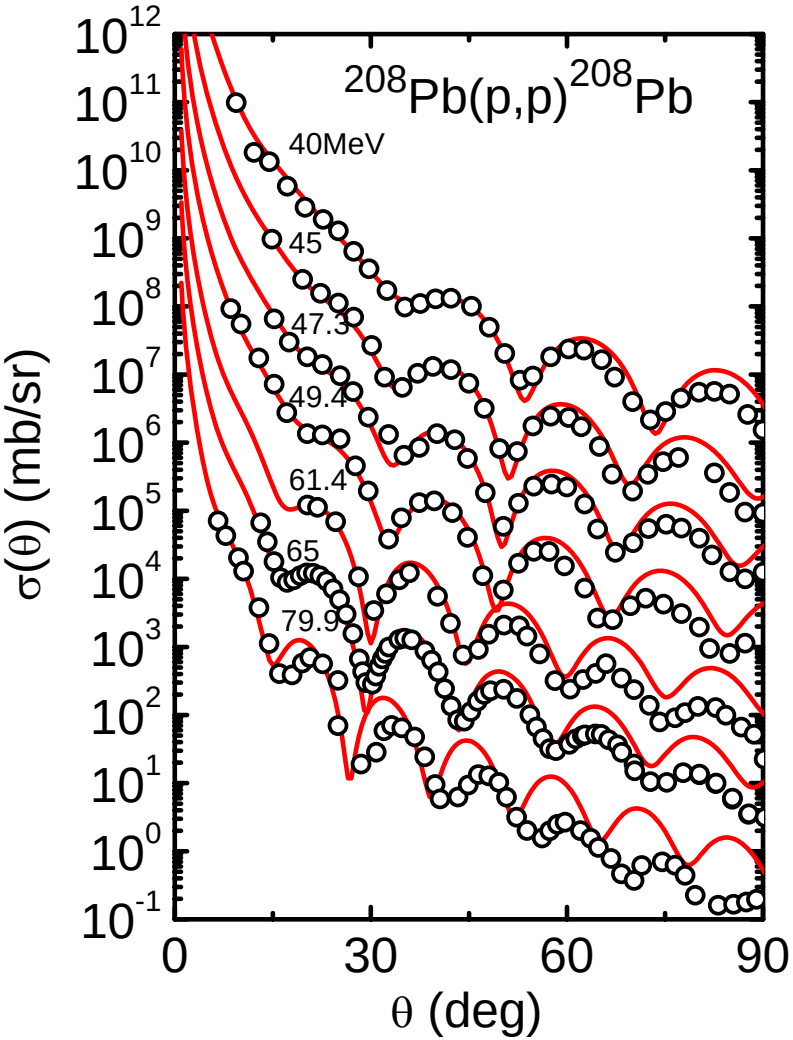
$m \rightarrow \infty$ $(g/m)^2 \rightarrow$ finite

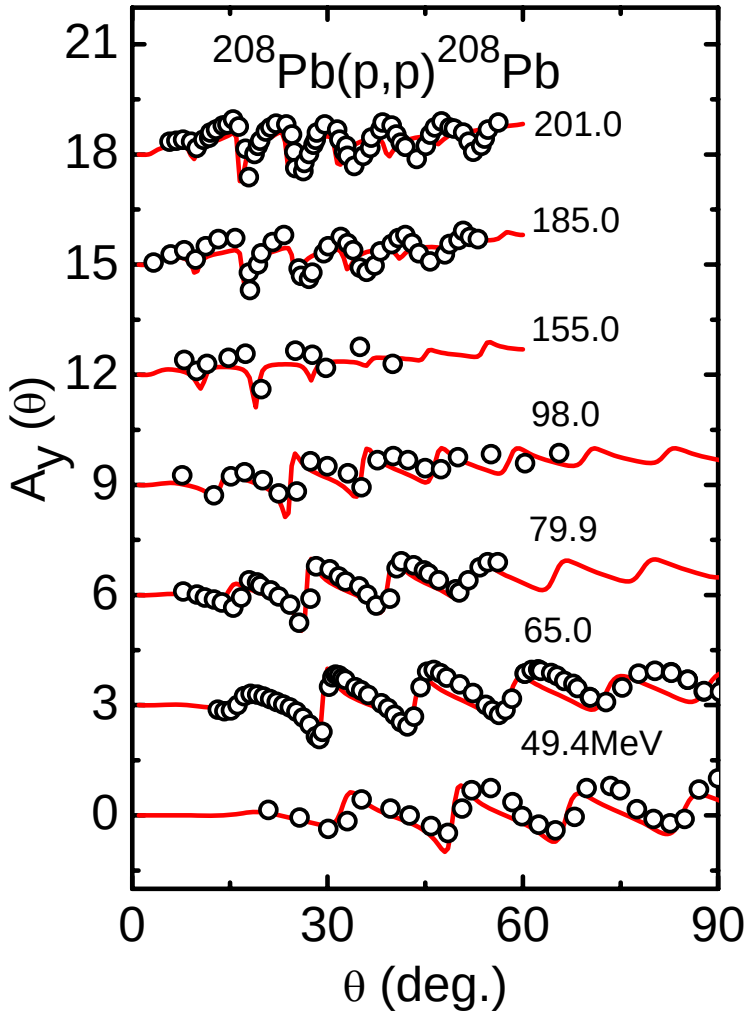


E. Shiller, H. Muether,

E Phys. J. A11(2001)15

$^{208}Pb\ (p, p)^{208}Pb$





J. Rong, Z. Y. Ma, PRC 06

Optical potential of Nucleus-Nucleus Scatterings

U_s^p, U_0^p

U_s^n, U_0^n

Real & Imaginary

$\rightarrow$ $V_{eff}^{p(n)}(r)$ Schroedinger eq. pot. U

folding

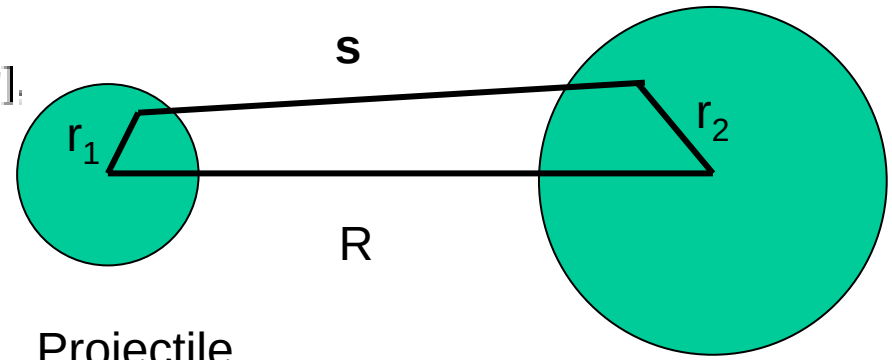
$\rightarrow$ $V_{\mathrm{DFM}}(\mathbf{R}) = \int \rho_1(\mathbf{r}_1)\rho_2(\mathbf{r}_2)V_{\mathrm{eff}}(\mathbf{s}, \rho, \varepsilon)d\mathbf{r}_1 d\mathbf{r}_2$

Real & Imaginary

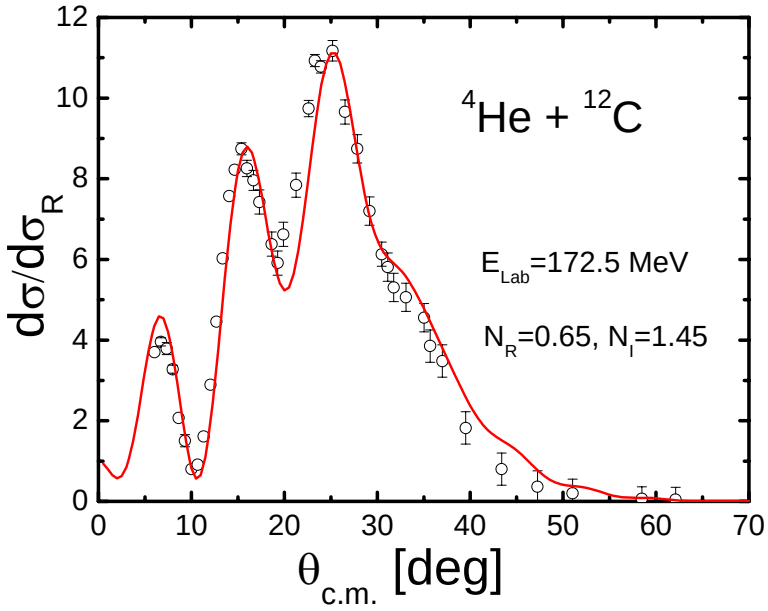
$$U_{\mathrm{eff}} = \frac{M}{E}U_s + U_0 + \frac{1}{2E}[(U_s)^2 - (U_0 + V_C)^2].$$

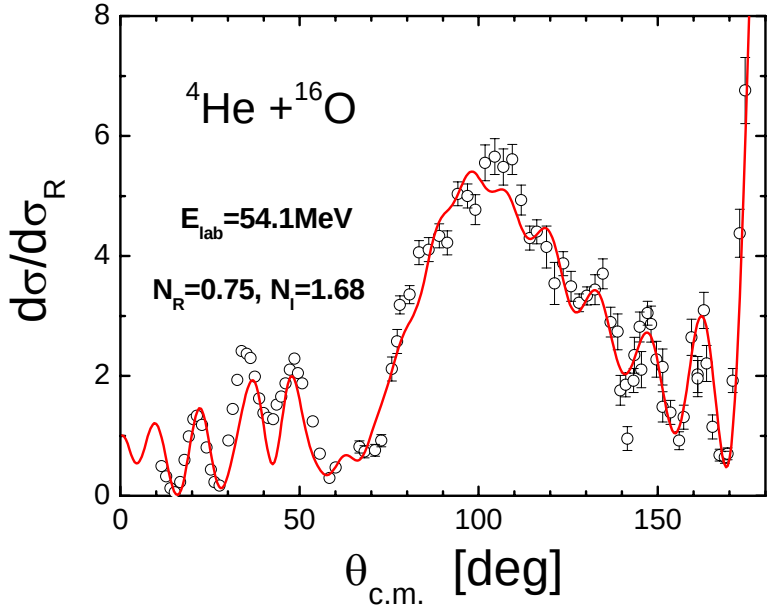
The *NN* effective interaction in the nuclear medium

$$V_{\mathrm{eff}} = U_{\mathrm{eff}}/\rho$$



α-nucleus scatterings

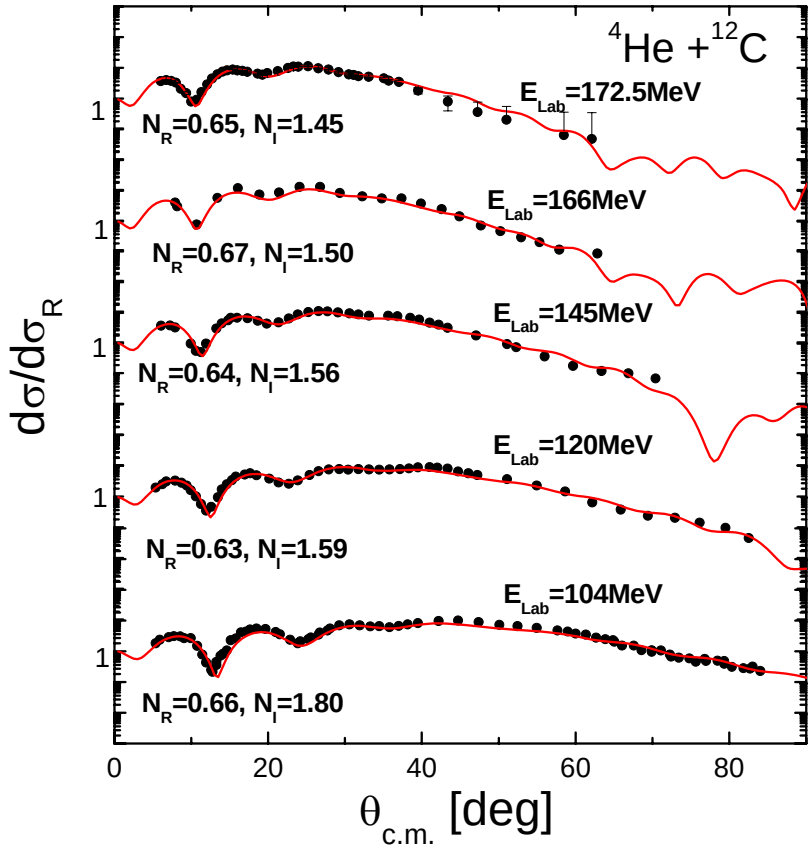


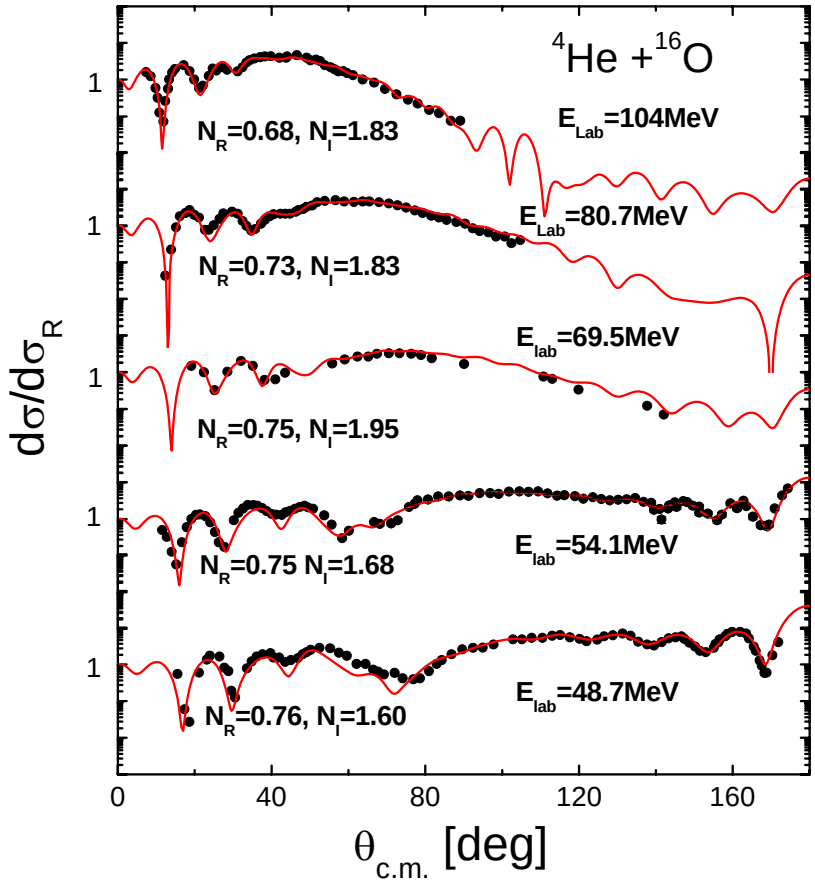


the cross sections calculated with the nucleon effective interaction based on the DBHF reproduce the experimental data quite well.

W Zou,Y Tian, and ZY Ma **78**, 064613 (2008)

α-nucleus scatterings



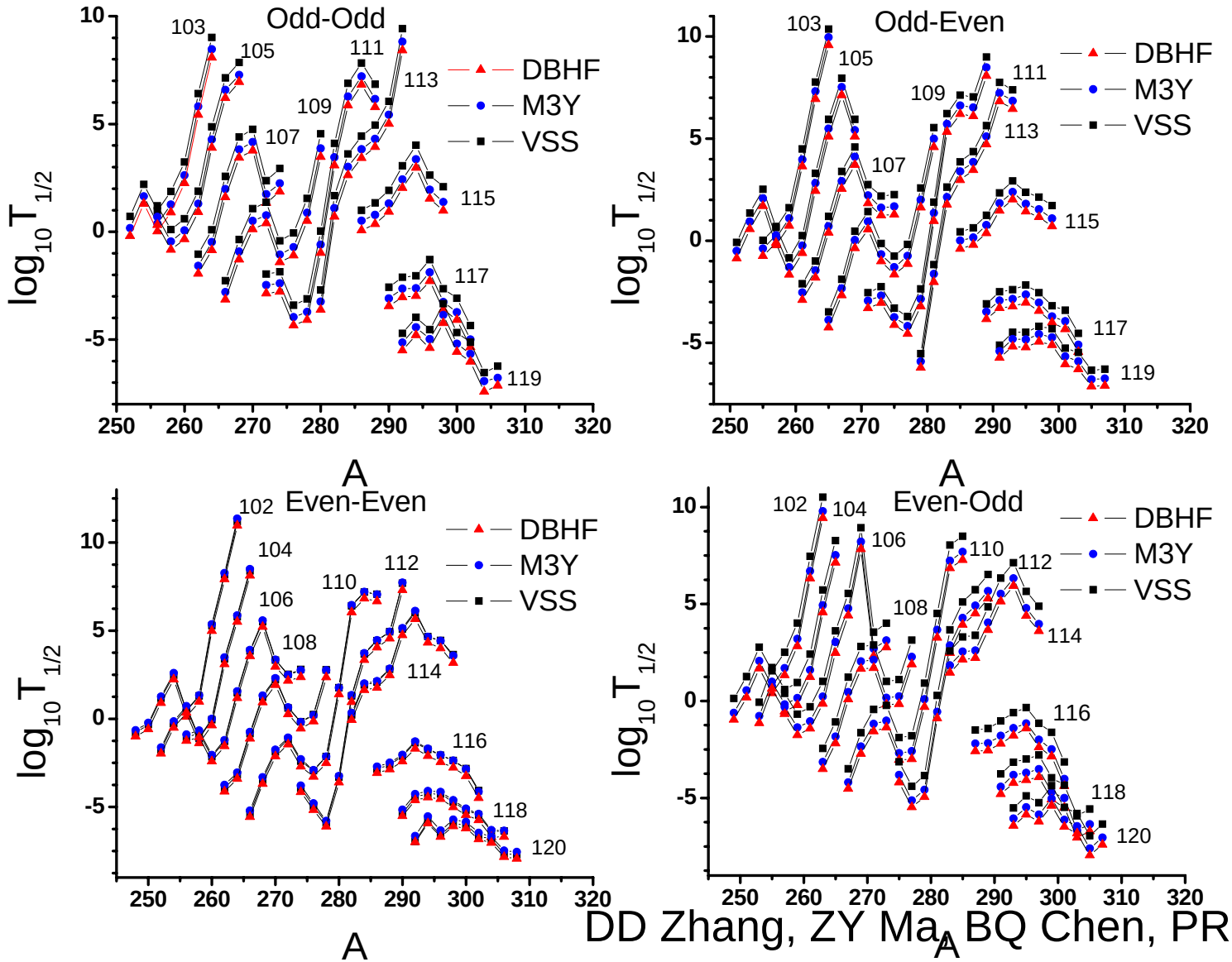


the renormalization factors are weak dependence on the energy

$N_R \approx 0.63–0.67$, $N_I \approx 1.5–1.8$ $N_R \approx 0.7–0.75$, $N_I \approx 1.7–1.8$

W Zou,Y Tian, and ZY Ma **78**, 064613 (2008)

α-decay half-lives of superheavy elments



DD Zhang, ZY Ma, BQ Chen, PRC81(10)044319

DBHF in asymmetric NM

- Subtracted G-matrix representation

the influence of the pion is dominantly given by the single-pion exchange,

reasonable to treat the bare interaction of the π and η separately to the rest.

After subtraction of the bare interaction of the η - and π -meson the remainder is the subtracted *G* -matrix,

$$T_{\mathrm{Sub}} = T - V_{\pi\eta}$$

E. N. E. van Dalen, C. Fuchs, and Amand Faessler, Nucl. Phys. **A744**, 227 (2004); Eur. Phys. J. A **31**, 29 (2007).

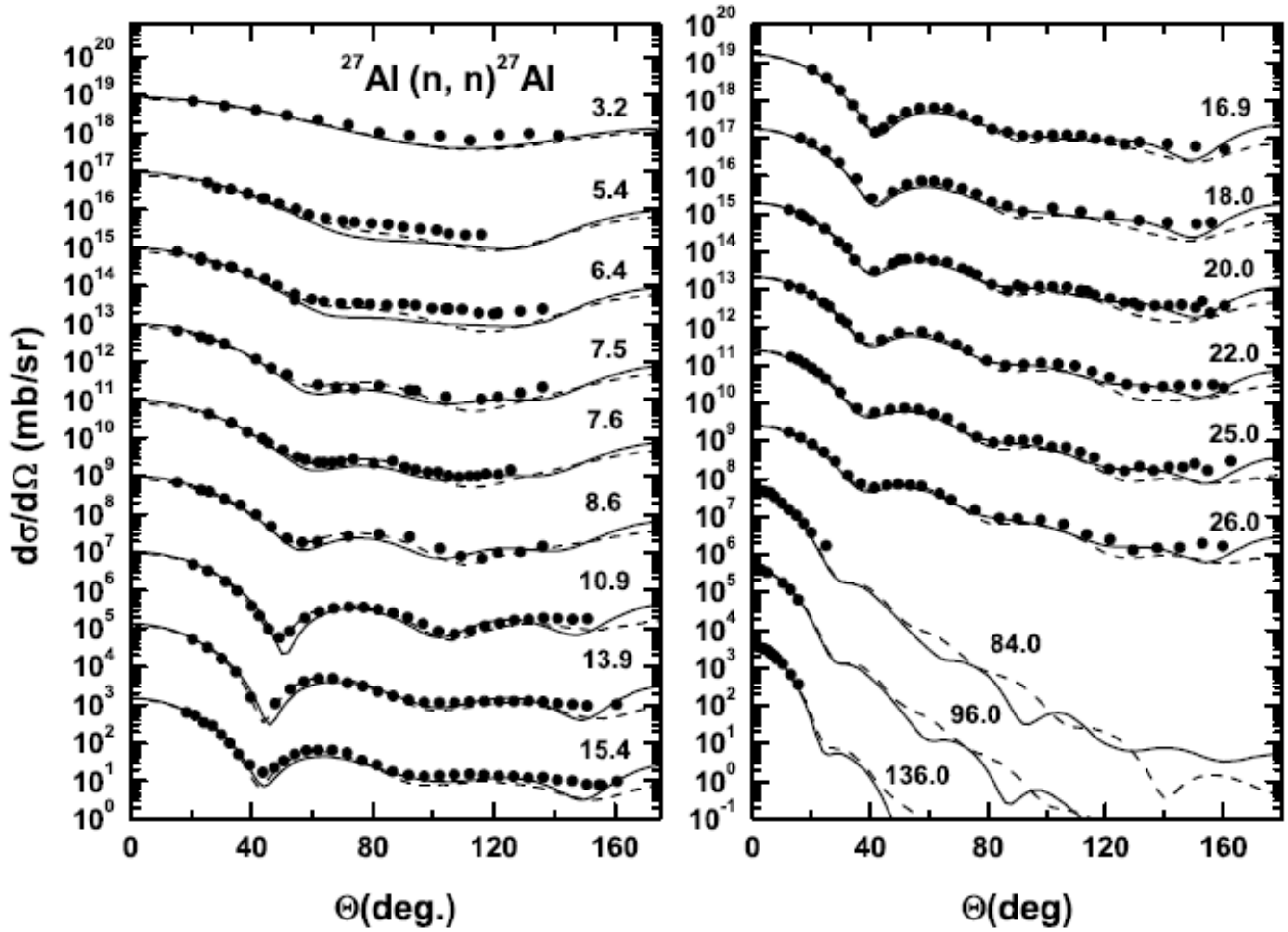
Systematic Study of RMOP

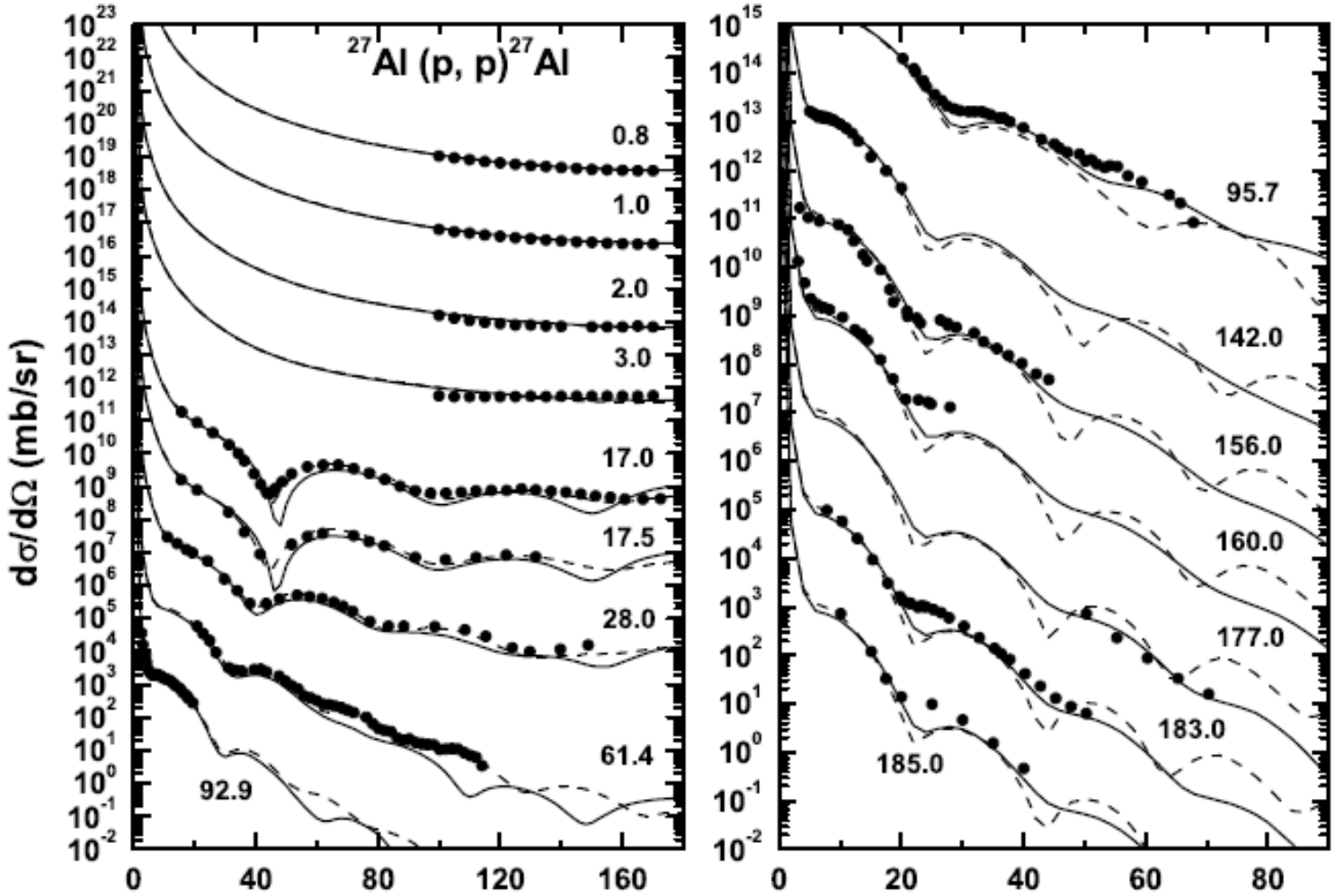
Energy region： **0.1 — 250MeV**

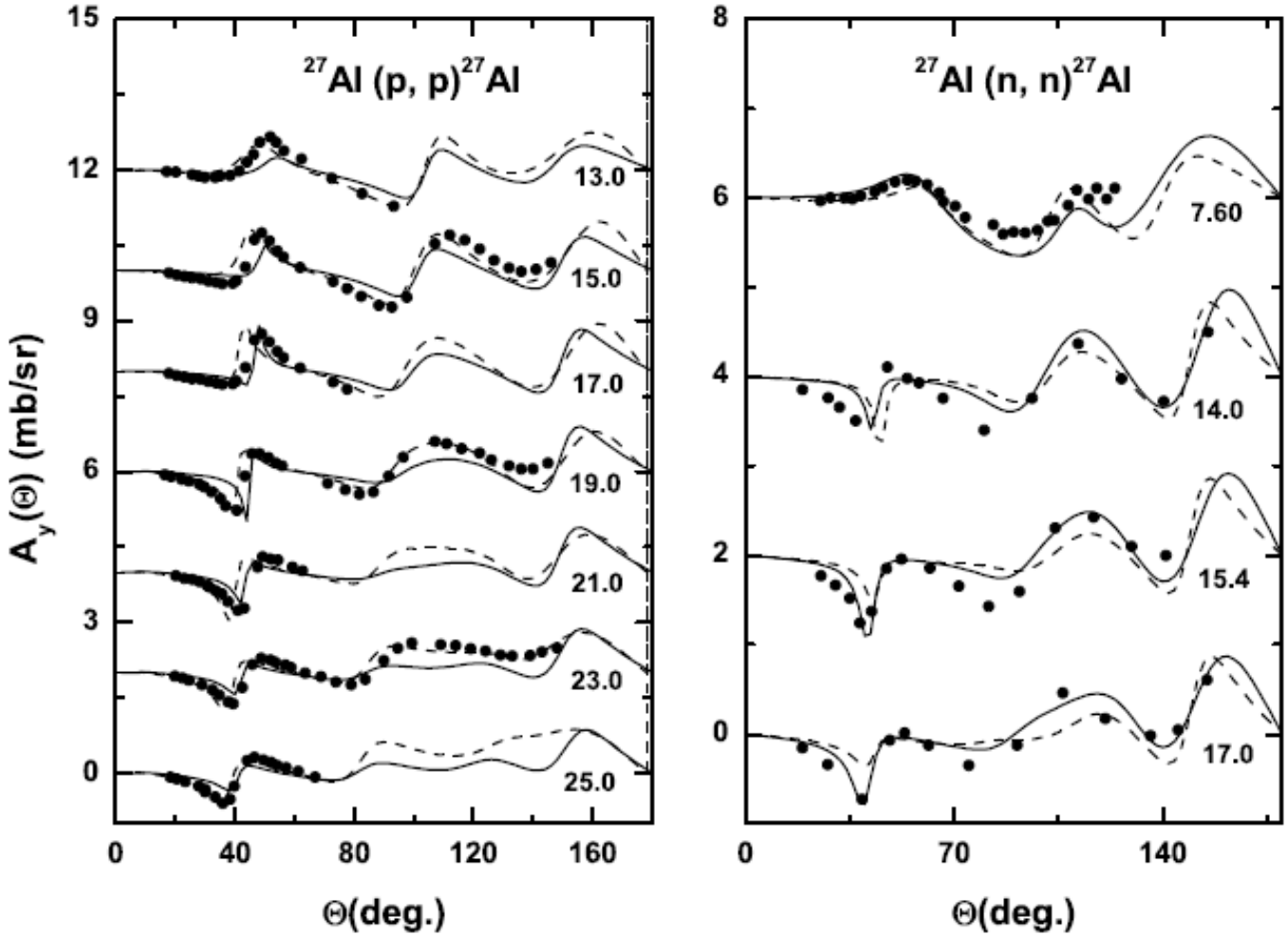
Target mass number (A)： **^{12}C — ^{238}U 28 nuclei**

Induced nuclei: n, p

Improved LDA


^{27}Al (n, n)^{27}Al
3.2
5.4
6.4
7.5
7.6
8.6
10.9
13.9
15.4
16.9
18.0
20.0
22.0
25.0
26.0
84.0
96.0
136.0
dσ/dΩ (mb/sr)
Θ(deg.)
Θ(deg)


^{27}Al (p, p)^{27}Al
dσ/dΩ (mb/sr)
0.8
1.0
2.0
3.0
17.0
17.5
28.0
61.4
92.9
95.7
142.0
156.0
160.0
177.0
183.0
185.0


^{27}Al (p, p)^{27}Al
^{27}Al (n, n)^{27}Al
$A_y(\Theta)$ (mb/sr)
Θ(deg.)
Θ(deg.)
13.0
15.0
17.0
19.0
21.0
23.0
25.0
7.60
14.0
15.4
17.0
0
40
80
120
160
0
70
140
0
3
6
9
12
15
0
2
4
6
8

Summary

- The relativistic microscopic optical potential is obtained from DBHF G matrix in nuclear matter
- The OMP is of density, asymmetry parameter and energy dependence, LDA is used for finite nuclei. The RMOP could well describe the p – A scattering data and isospin dependence of the RMOP.
- Microscopic optical potential for nucleus-nucleus elastic scattering, which includes the real and imaginary parts is obtained by folding with the density.
- New microscopic MOP from DBHF G matrix with density, energy and asymmetry dependence are available and under investigation

恭贺

卓益忠老师八十华诞！

福如东海

寿比南山

Thanks