RPA CORRECTION TO THE OPTICAL POTENTIAL

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Parametrized potentials are very useful but only in the range of the fit and they are mostly local.

Long time quest for more microscopic potentials
- From NN realistic interaction: nuclear matter, FRPA
- From NN effective interaction: Skyrme or Gogny force

Microscopic potentials are non-local and energy dependent
- Need for tools to determine bound states and continuum states
- Need for reaction tools able to deal with non-locality.

Microscopy can be a guide line for new parametrized non-local potential
Microscopic N-nucleus optical potential

- Nucleon scattering off stable nuclei
  - Nuclear structure $\rightarrow$ Nuclear reaction
  - Elastic scattering
  - RPA (double closed-shell, spherical symmetry)
  - Gogny force / G-matrix (Melbourne, Santiago)
Nuclear matter approach

Proton elastic scattering off $^{208}$Pb (M. Dupuis, et al., PRC 73, 014605 (2006).)

- Melbourne G-matrix
- DWBA98 (J. Raynal)
- No parameter

Good agreement with experiment at high incident energy

⇒ Lack of absorption below 60 MeV.
Nuclear structure approach

“Optical potential for low-energy neutrons”,
(N. Vinh Mau, A. Bouyssy. NPA 257 (1976) 189-220.)
Coupling to collective states of the target nucleus

Ingredients:
- Green’s functions formalism.
- Second order double counting issue.
- Absorption at small incident energy

V. Bernard and N.V. Giai, NPA 327, 397 (1979)
Integro-differential Schrödinger equation

- Non-local and energy dependent optical potential.
- Integro-differential Schrödinger equation,

\[
\left[ \frac{d^2}{dr^2} + \frac{l(l + 1)}{r^2} - k^2 \right] f_{jl}(r) + \int dr' U_{jl}(r, r')f_{jl}(r') = 0
\]

No localization of the potential

- We use a modified version of DWBA98 code for continuum wave functions. (J. Raynal. computer code DWBA98, 1998, (NEA 1209/05).)
- We determine bound states for a non-local potential in coordinate space (Important to get the right asymptotic behavior of the wave function).
First strategy: G-Matrix / RPA-D1S

G-MATRIX
MELBOURNE SANTIAGO

$V_{BHF}$

SCHRODINGER NL
DWBA98 CODE RAYNAL

CROSS SECTION
First strategy: G-Matrix / RPA-D1S

- G-Matrix
  - Melbourne Santiago

- $V_{BHF} + V_{RPA}$

- Intermediate Distorted Wave

- Nuclear Structure
  - RPA/D1S
    - Decharge & Gogny

- Double Counting with G-Matrix
  - RPA Correction

- Schrödinger NL
  - DWBA98 Code
    - Rynal

- Cross Section
Second strategy: HF + RPA-D1S
Imaginary part of $V_{RPA}$

Coupling to $3^-$ states with $E_{exc} < 30$ MeV.

Proton scattering off $^{208}$Pb, $ImV_{RPA}$.

- $E_{inc} = 40$ MeV
- $E_{exc} < 30$ MeV $\rightarrow$ 115 states.
- Intermediate $\rightarrow$ Plane wave
- $V_{RPA}^{jl}(r, r)$

$$V_{RPA}^{jl} = \langle j,l| \begin{array}{c} \uparrow \\ 3^- \end{array} | j,l \rangle$$
Imaginary part of $V_{RPA}$ with incident energy

$V_{RPA}$: Coupling to the first $3^{-}, E_{exc} = 3.4$ MeV

Proton scattering off $^{208}$Pb for several incident energies.

$$W(R, s) = \sum_{lj} \frac{2j + 1}{4\pi} Im V_{RPA}^{lj}(r, r')$$

with $R = \frac{1}{2}(r + r')$ and $s = r - r'$

$\rightarrow$ Absorption coming from coupling to a given RPA state decreases as the incident energy increases
Non-locality of the imaginary part of $V_{RPA}$

$V_{RPA}$: Coupling to the first $3^-$ $E_{exc} = 3.4$ MeV

- Surface picked contribution: collectivity
- Gaussian like non-locality $\rightarrow$ Perey & Buck
Cross Section: $V_{BHF} + V_{RPA}$ neutron-$^{40}$Ca @ 40 MeV

- $n+^{40}$Ca @ 30 MeV
  Contribution from different excitations of the target.

- **Cross section:** Melbourne G matrix
  - $n+^{40}$Ca @ 40 MeV
  - Melbourne + RPA/D1S
Reaction cross section n/p off $^{40}$Ca

- HF+RPA with D1S (Intermediate plane wave)
- Comparison with reaction cross section obtained with König-Delaroche (KD) global potential.
- Distorted waves are expected to lead to an enhancement of the absorption
- Coupled channels calculation gives less absorption considering only inelastic couplings. They emphasize the contribution of the deuteron pickup channel. *G. Nobre et al., PRL 105, 202502 (2010).*
Summary

- RPA correction deals with part of the observed absorption but other channels would be needed: deuteron channel, charge exchange.
- We develop tools to get bound as well as scattering states using any non-local potential.
- Use of intermediate distorted waves is expected to lead to an enhancement of absorption.

Perspectives

- A systematic study of: $V_{RPA}$ is in progress.
- Microscopic potentials can guide new global parametrizations.
- Extension to QRPA nuclei.
- Add of damping widths in the propagators.
- Coupled channels with non-local potentials (deformed target).