Effective Field Theory and Quantum Monte Carlo Methods in Nuclear Physics

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PhD WorkShop
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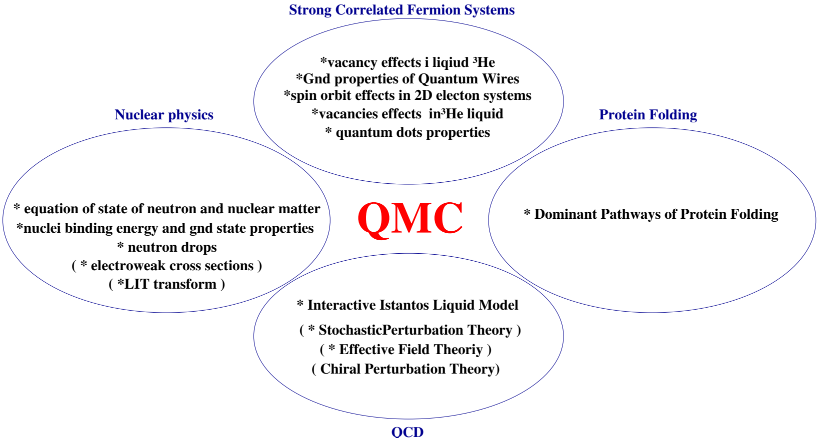
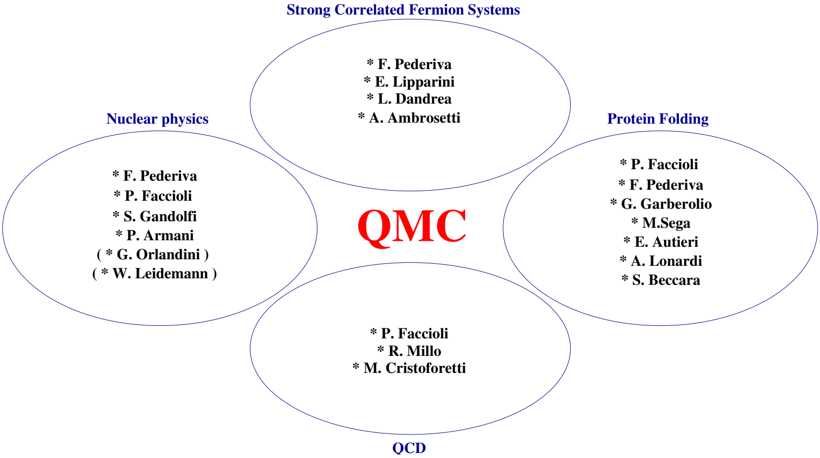
Research areas



People


Strong Correlated Fermion Systems
* F. Pederiva
* E. Lipparini
* L. Dandrea
* A. Ambrosetti
Nuclear physics
* F. Pederiva
* P. Faccioli
* S. Gandolfi
* P. Armani
(* G. Orlandini)
(* W. Leidemann)
QMC
Protein Folding
* P. Faccioli
* F. Pederiva
* G. Garberolio
* M.Sega
* E. Autieri
* A. Lonardi
* S. Beccara
* P. Faccioli
* R. Millo
* M. Cristoforetti
QCD

The Nuclear Problem

Nuclear interaction

based on:

- phenomenological potentials (Argonne, Urbana).
- potentials derived from Effective Field Theories (EFT).
- Effective Field Theories.

Computational exact methods

Methods using potentials:

- Shell–model ($A \leq 6$ o $A \leq 12$).
- Green Function Monte Carlo (GFMC) ($A \leq 12$).
- Auxiliary Field Diffusion Monte Carlo (AFDMC) ($A \lesssim 100$).

EFT methods:

- lattice simulations ($A \leq 4$).

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Monte Carlo Methods

Schrödinger equation in imaginary time

$$|\Psi(0)\rangle = \sum_i c_i|\phi_i\rangle \qquad H|\phi_i\rangle = E_i|\phi_i\rangle$$

$$-\frac{d}{d\tau}|\Psi(\tau)\rangle = (H - E_0)|\Psi(\tau)\rangle$$

$$|\Psi(\tau)\rangle = e^{-\tau(H-E_0)}|\Psi(0)\rangle \xrightarrow[\tau\to\infty]{} c_0|\phi_0\rangle$$

Diffusion Monte Carlo

$$\langle r|\Psi(\tau + d\tau)\rangle = \int \langle r|e^{-d\tau(H-E_0)}|r'\rangle\langle r'|\Psi(\tau)\rangle dr'$$

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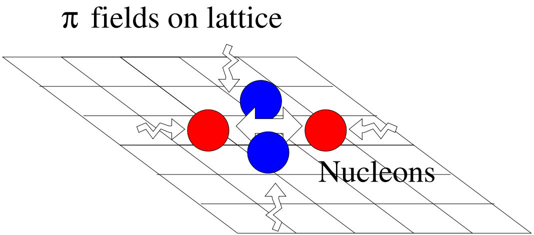
Diffusion Monte Carlo

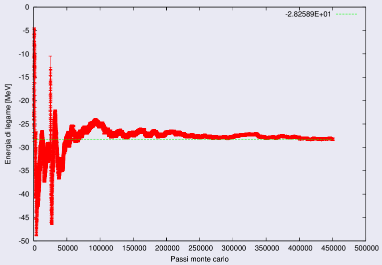
$$\langle r, s|\Psi(\tau + d\tau)\rangle = \int \sum_{s'} \langle r, s|e^{-d\tau(H-E_0)}|r', s'\rangle\langle r', s'|\Psi(\tau)\rangle dr'$$

Effective Field Theory (EFT)

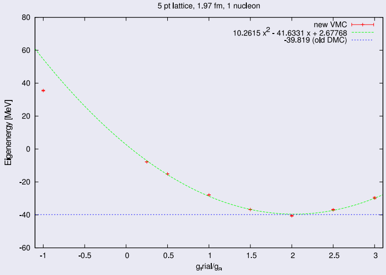


- Fundamental Theory (QCD) ⇒ EFT
- GFMC accurate method ⇒ determination of effective parameters
- AFDMC ⇒ many–body systems could be studied

^4He Binding Energy



Nucleon Eigenenergy



- method tested on trial ^4He system
- some enhancement are necessary for an accurate fit of effective parameters

Future Developments

As a first step

- compute effective Hamiltonian parameters
- compute binding energy of few–body nucleon systems

As next step

- determine equation of state of neutron and nuclear matter (astrophysical interest)
- improve EFT Hamiltonian to next orders

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