Quantum Monte Carlo formalism for dynamical pions and nucleons

Lucas Madeira[1], Alessandro Lovato[2,3], Francesco Pederiva[2,4], and Kevin E. Schmidt[5]

[1] University of São Paulo, Brazil
[2] Trento Institute for Fundamental Physics and Applications, Italy
[3] Argonne National Laboratory, USA
[4] University of Trento, Italy
[5] Arizona State University, USA

[1] madeira@ifsc.usp.br

Nucleon-nucleon interaction

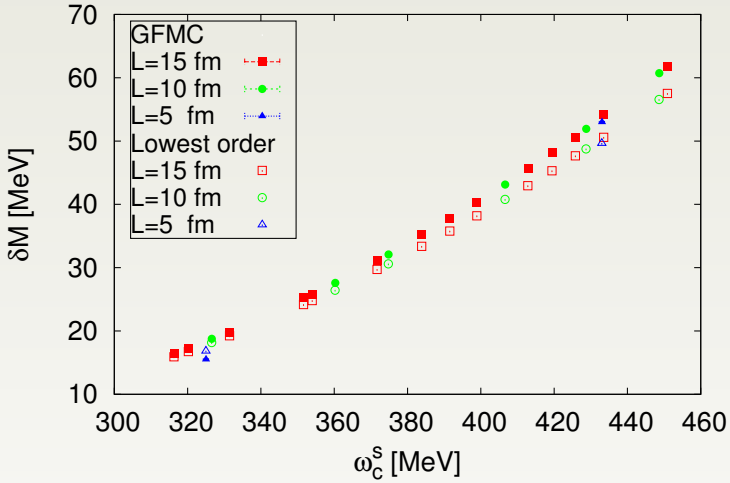
- Major open problem in nuclear physics: how to construct a nucleon-nucleon (NN) interaction potential from first principles?
- Pion dynamics is constrained by chiral symmetry
- Effective Field Theory (EFT) $\rightarrow$ identify soft and hard scales, degrees of freedom and relevant symmetries
- Heavy baryon leading order chiral Lagrangian density

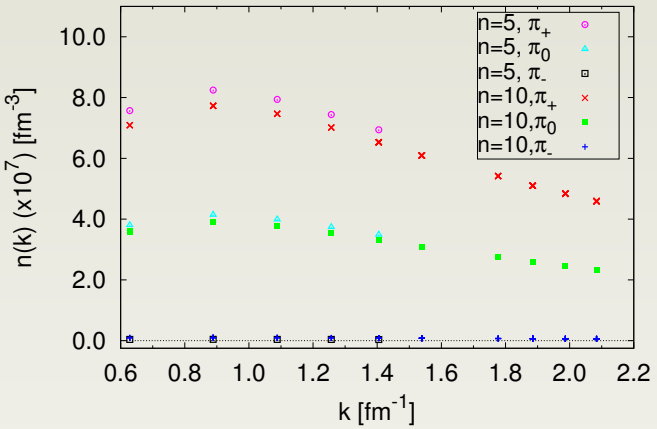
$$\begin{aligned}\mathcal{L}_0 = & \frac{1}{2}\partial_\mu \pi_i \partial^\mu \pi_i - \frac{1}{2} m_\pi^2 \pi_i \pi_i \\ & + N^\dagger \left[i\partial_0 + \frac{\nabla^2}{2M_0} - \frac{1}{4f_\pi^2} \epsilon_{ijk} \tau_i \pi_j \partial_0 \pi_k - \frac{g_A}{2f_\pi} \tau_i \sigma^j \partial_j \pi_i - M_0 \right] N \\ & - \frac{1}{2} C_S (N^\dagger N)(N^\dagger N) - \frac{1}{2} C_T (N^\dagger \sigma_i N)(N^\dagger \sigma_i N)\end{aligned}$$

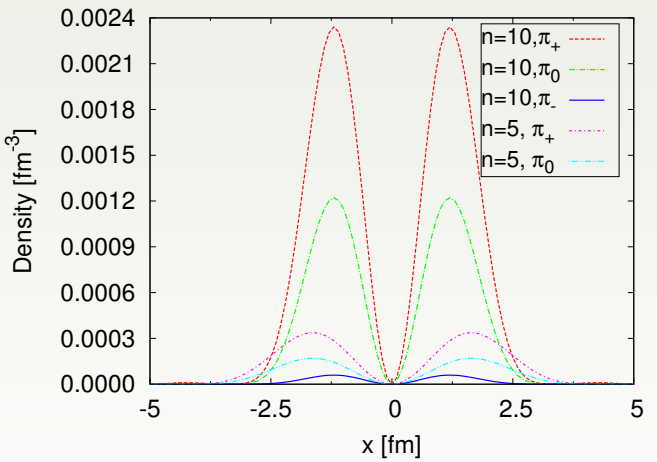
- Standard quantum Monte Carlo simulations: pion degrees of freedom are replaced with potentials
- Our goal: to include explicit pion degrees of freedom in QMC simulations

One-nucleon properties

- Mass renormalization δM
- Pion cloud distributions



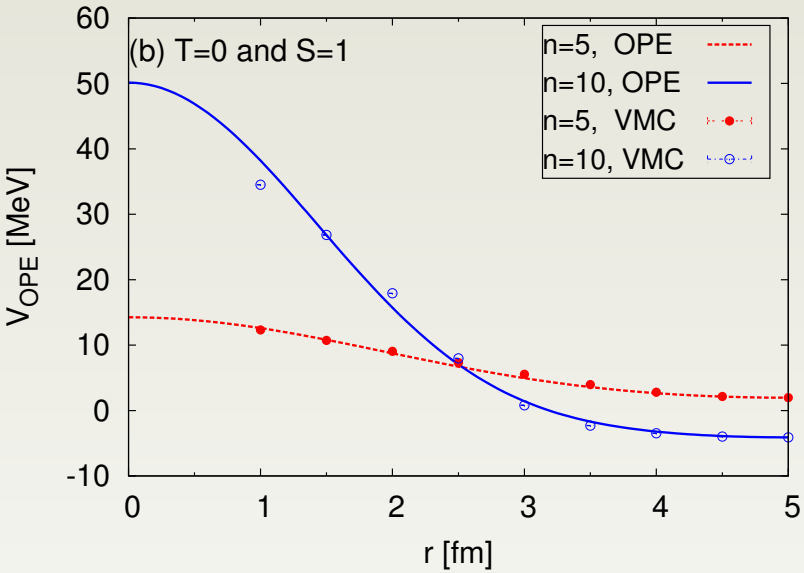


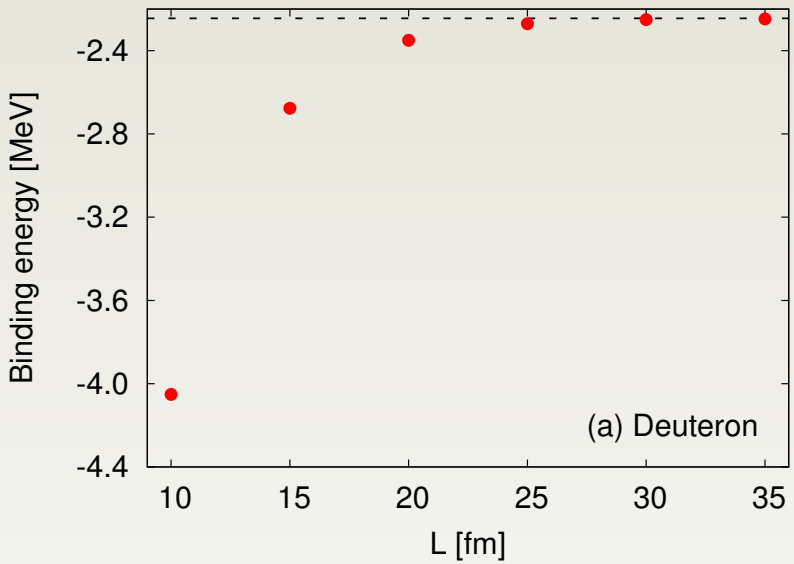


Lucas Madeira et al. "Quantum Monte Carlo formalism for dynamical pions and nucleons". In: *Phys. Rev. C* 98.3 (2018).

Two-nucleon properties

- Long-range behavior $\rightarrow$ one-pion exchange
- Physical two-nucleon systems: two neutrons and the deuteron





- Our goal is to compute properties of light-nuclei with explicit pion degrees of freedom
- Currently, we are performing $A = 3$ and 4 calculations

Lucas Madeira et al. "Quantum Monte Carlo formalism for dynamical pions and nucleons". In: *Phys. Rev. C* 98.3 (2018).