

Neutron Matter and Drops

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■ Neutron Matter

- EOS
- Computational Aspects
- Pairing Gap and Dispersion
- Other Quantities

■ Neutron Drops

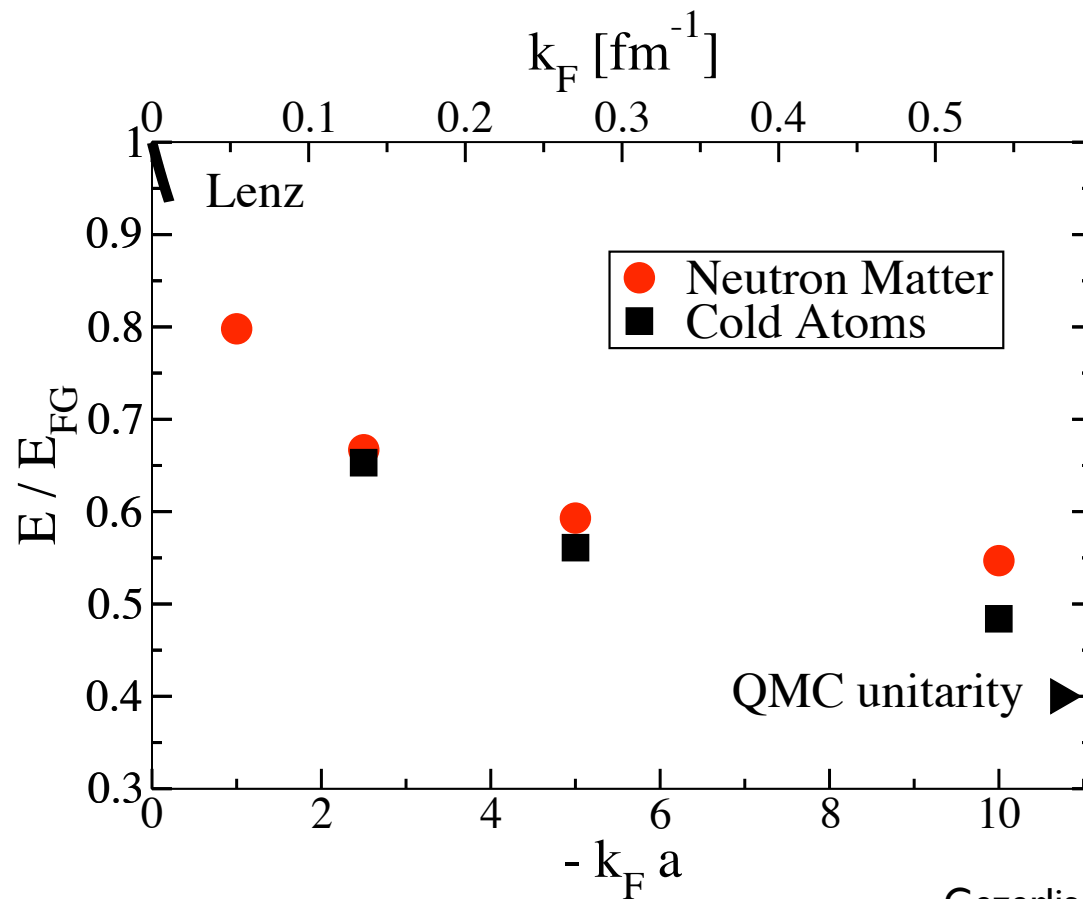
- Energies and Saturation
- Comparing ab-initio energies with Skyrme
- Pairing and Single-Particle Energies

■ Future

Neutron Matter EOS

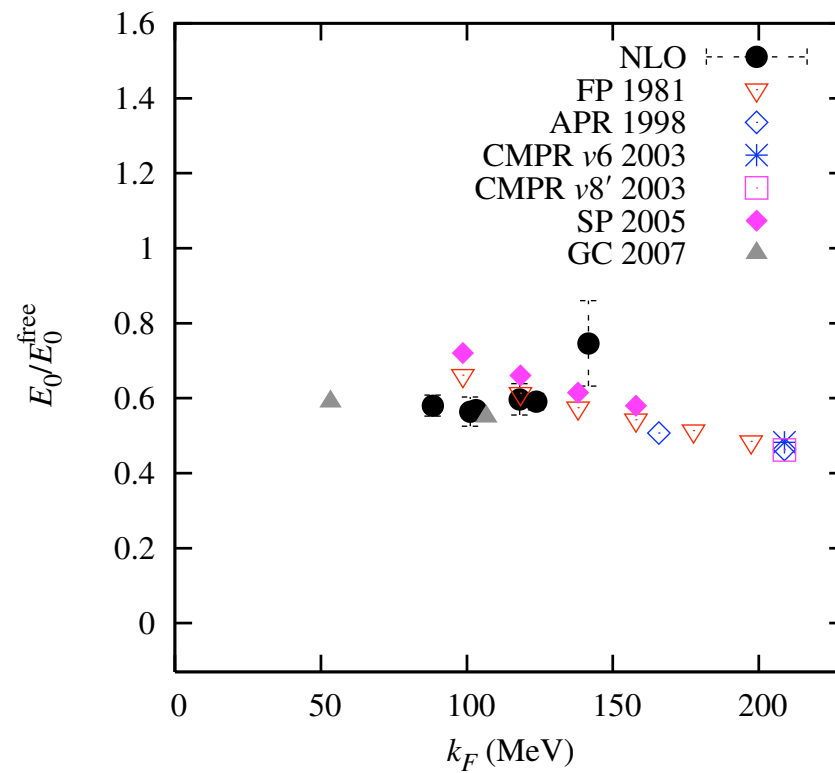
Neutron Matter properties less well-known than Nuclear Matter near equilibrium density
Ab Initio calculations can provide guidance to the density functional

Equation of State at Low Densities



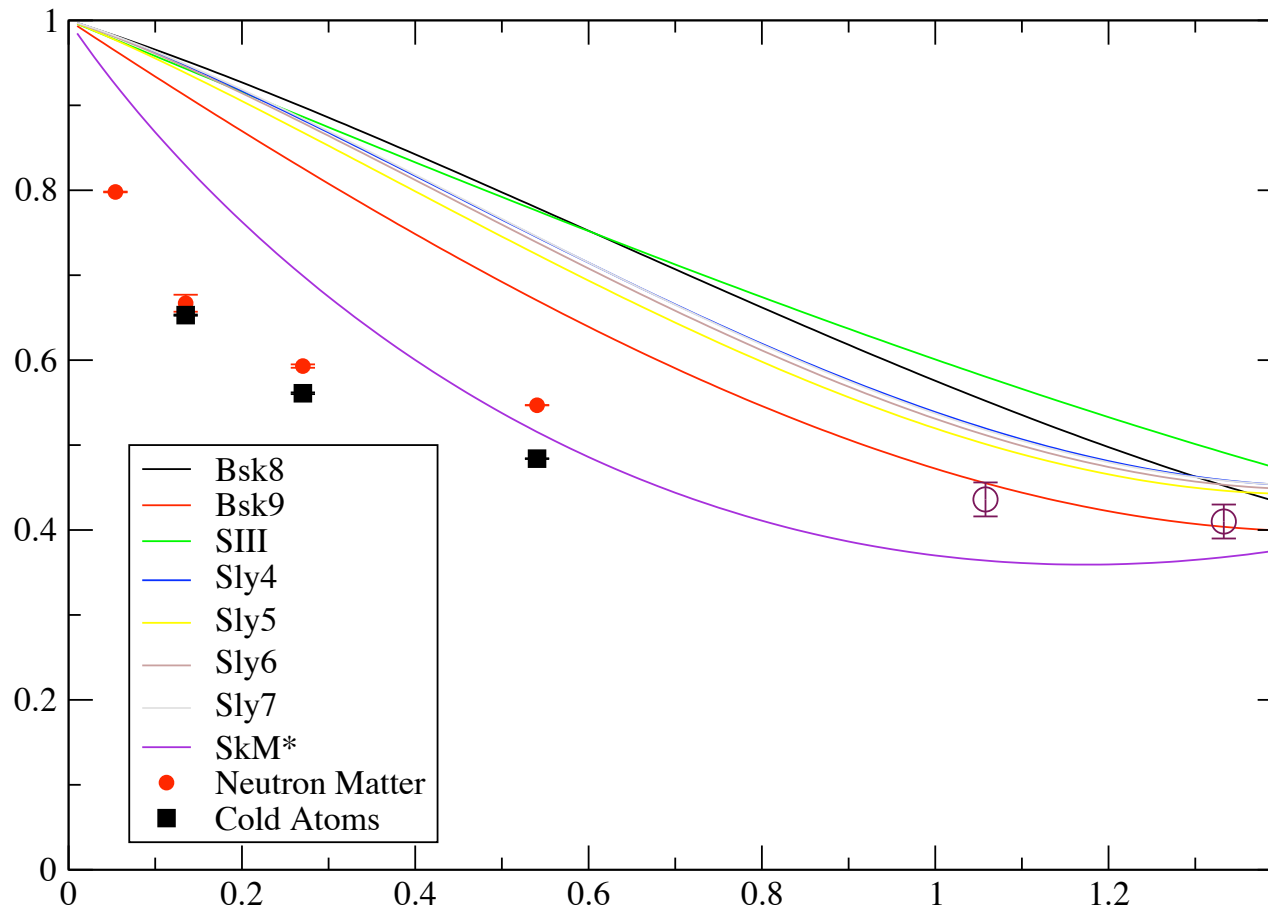
Gezerlis & Carlson, PRC 2008

Dilute Neutron Matter various simulations



Dean Lee (08)

Low Density Neutron Matter Microscopic vs. Skyrme



Computational Approach:

GFMC: sum over spin/isospin explicitly

Diffusion MC: spin-independent (s-wave interactions)

AFDMC: Monte-Carlo sums over spin/isospin

All algorithms are branching random walks:

Significant linear algebra at each step in the walk

Neutron Matter Diffusion Monte Carlo

~65 particles (scales like N^3)

Gap with even/odd staggering

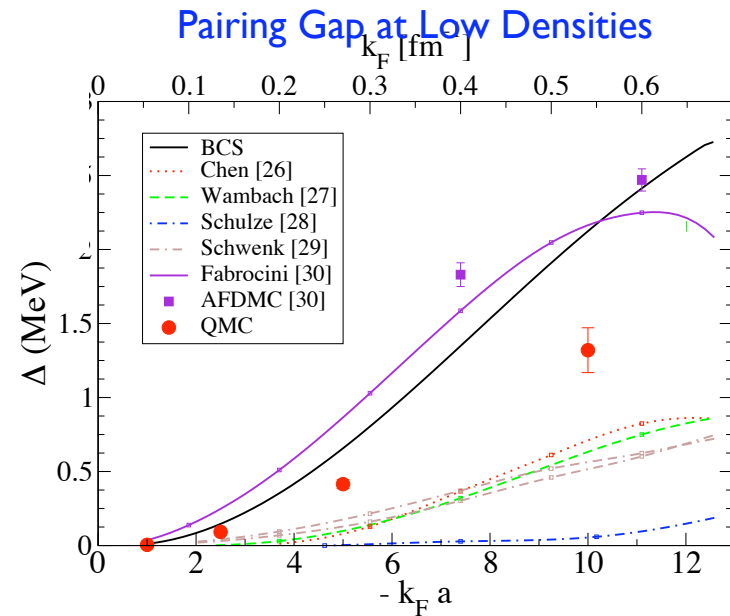
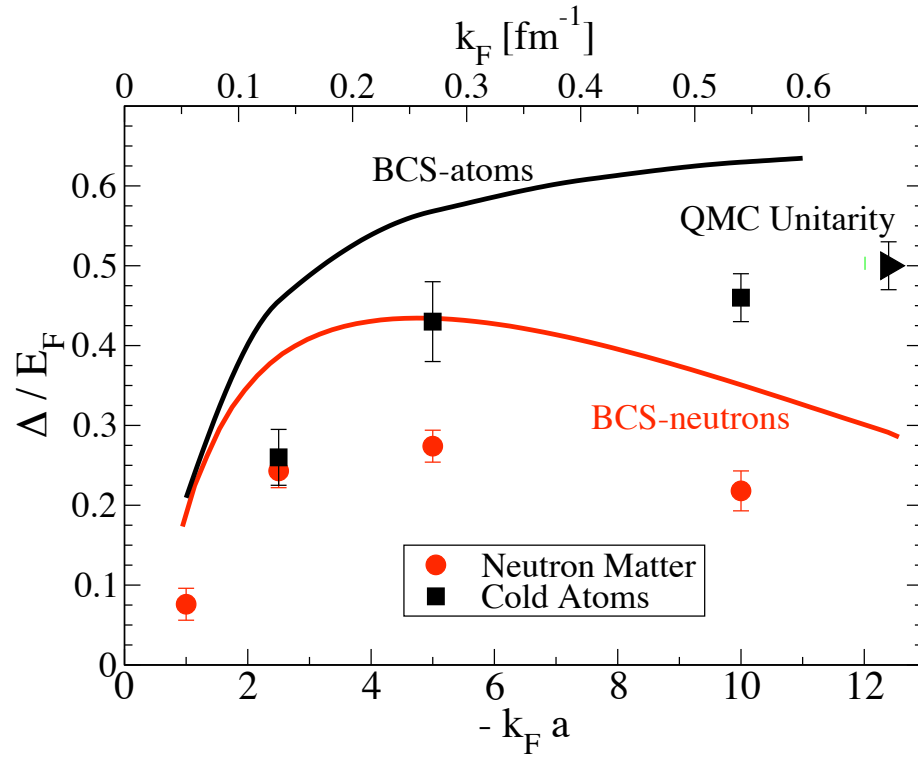
Need $\ll 1$ MeV accuracy

Each calculation (fixed ρ, N, k) takes of order 1/2 day on 1000 processors

approximately 1 Tflop on Franklin

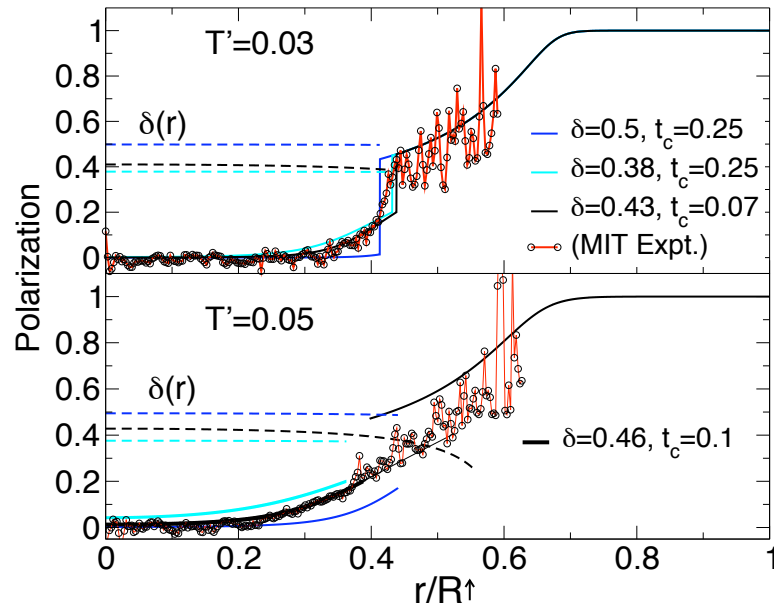
90% parallel efficiency up to 1000 processors

Neutron Matter Pairing Gap



Gezerlis and Carlson, PRC 08

Neutron Matter Pairing Gap

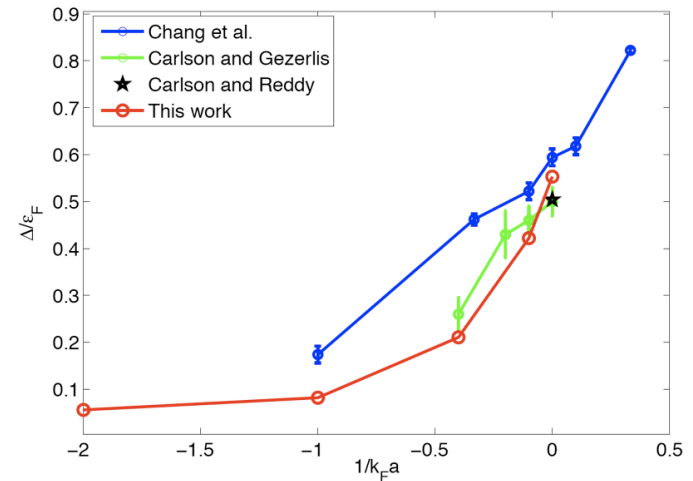


Analysis of cold atom experiments gives $\text{Gap}/E_f = 0.45$ (05).

Largest Gap/E_f in any system!

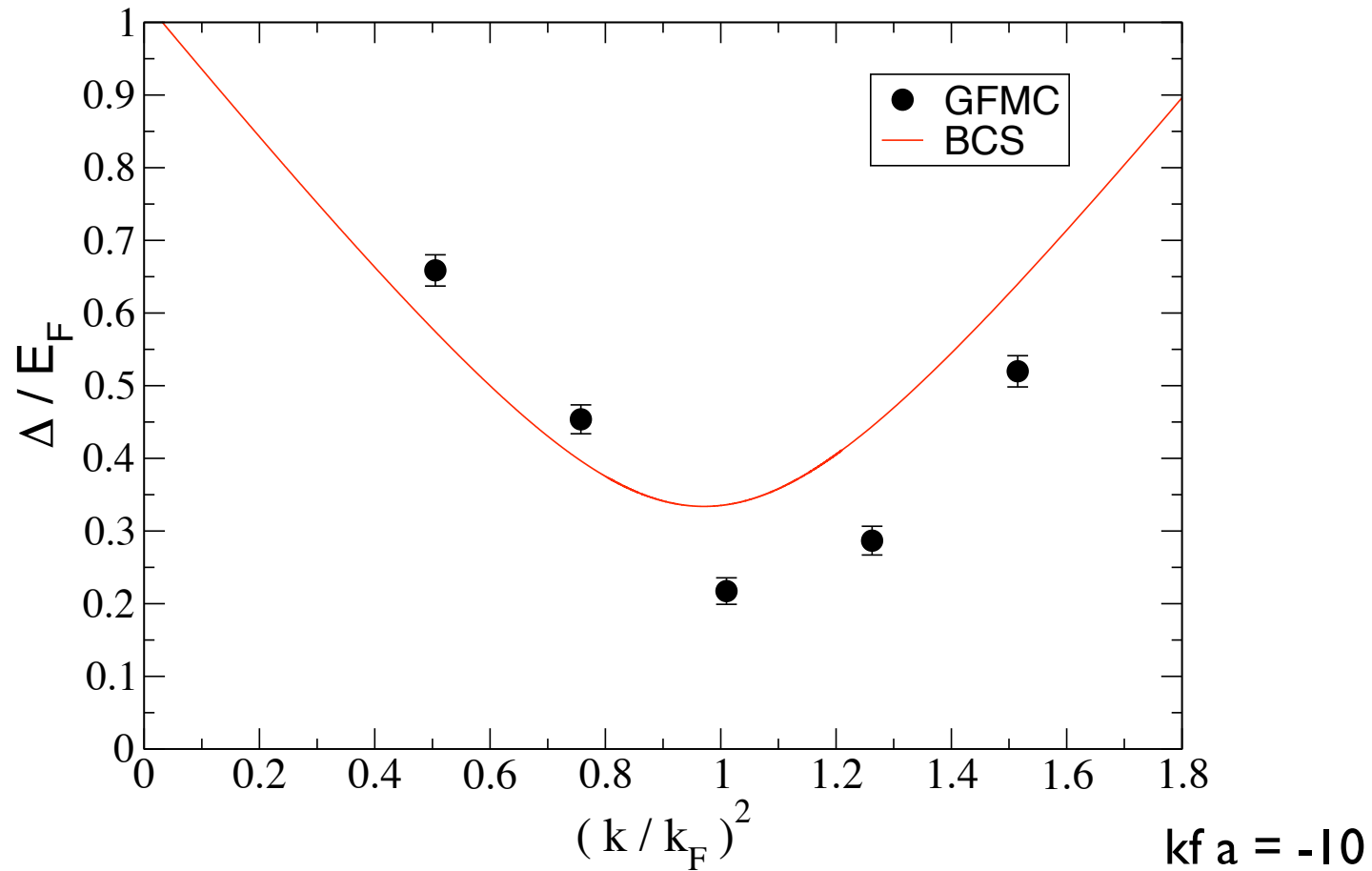
Carlson and Reddy, PRL 08

Pairing Gap for Atomic Gas
Experimentally confirmed to ~10%



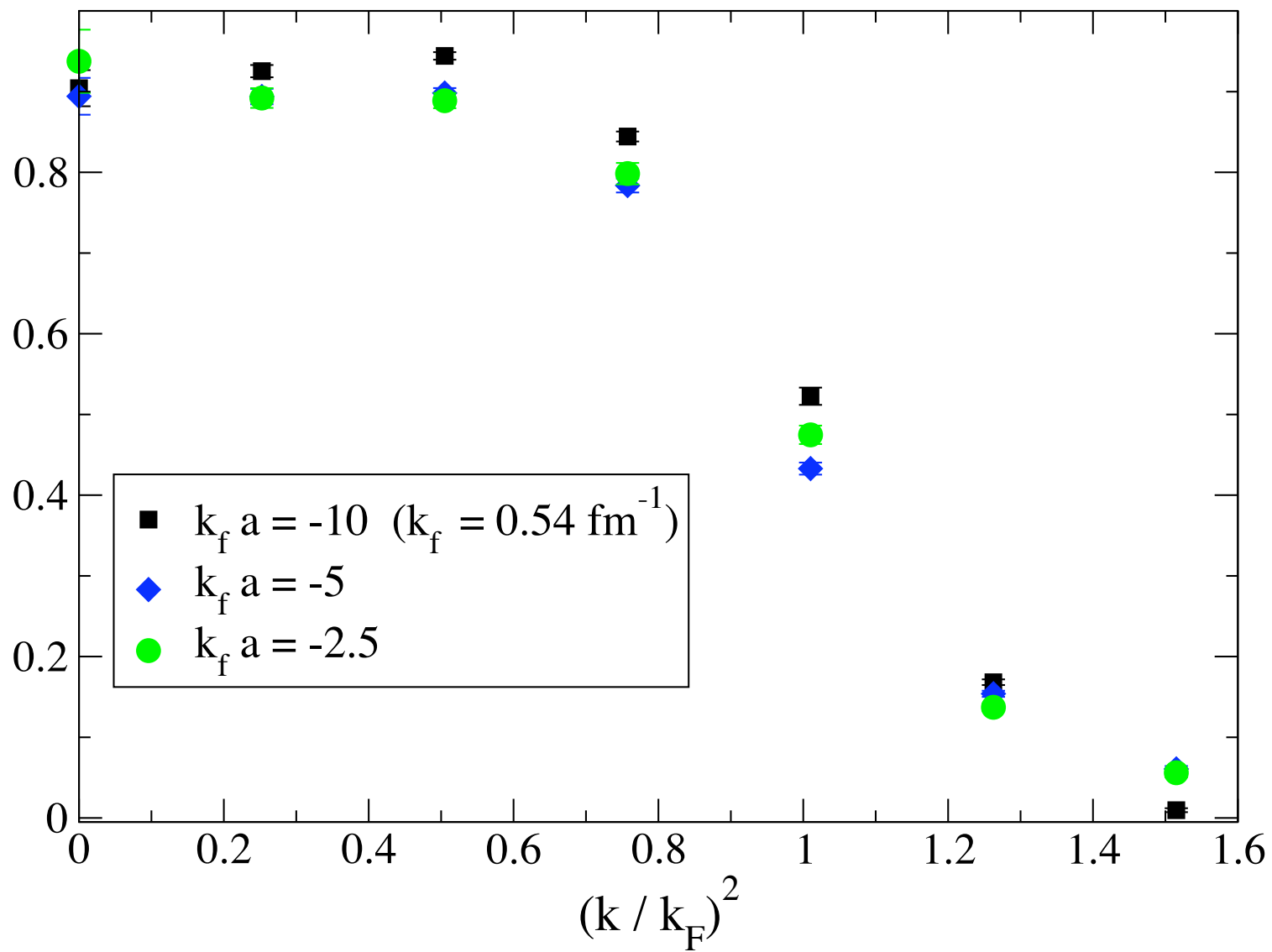
Calculations also agree;
new AFDMC calculation
much closer to DMC

New Calculations: Dispersion of Single-Particle States



Can be a constraint to Skyrme models
weak reaction rates, spin susceptibility,...
of interest in neutron stars

Momentum Distributions



Neutron Drops

Information beyond constant (local) density:

Adjustable External Potential

Woods-Saxon, Harmonic Oscillator
adjusts density, deformation, ...

Can compare microscopic theory and DF

Energies

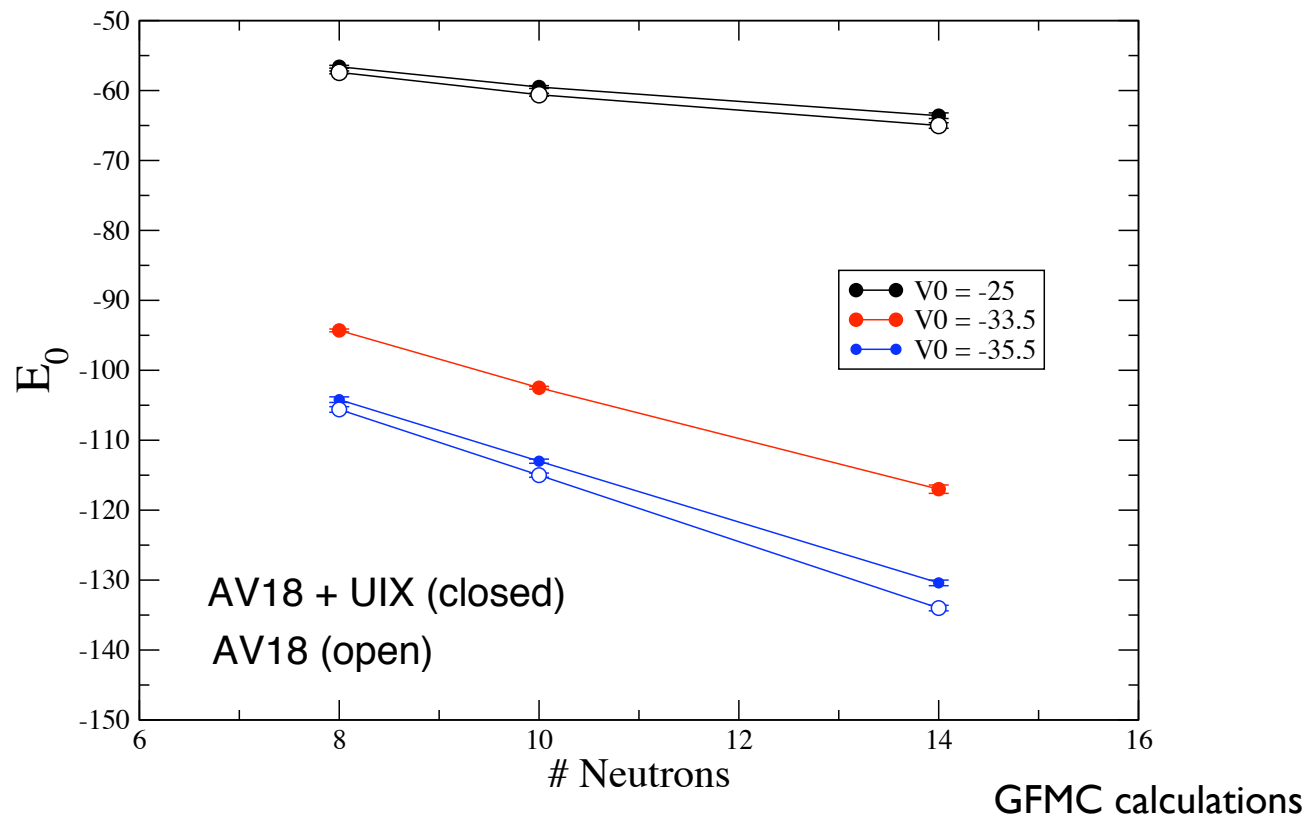
Density

Pairing

etc.

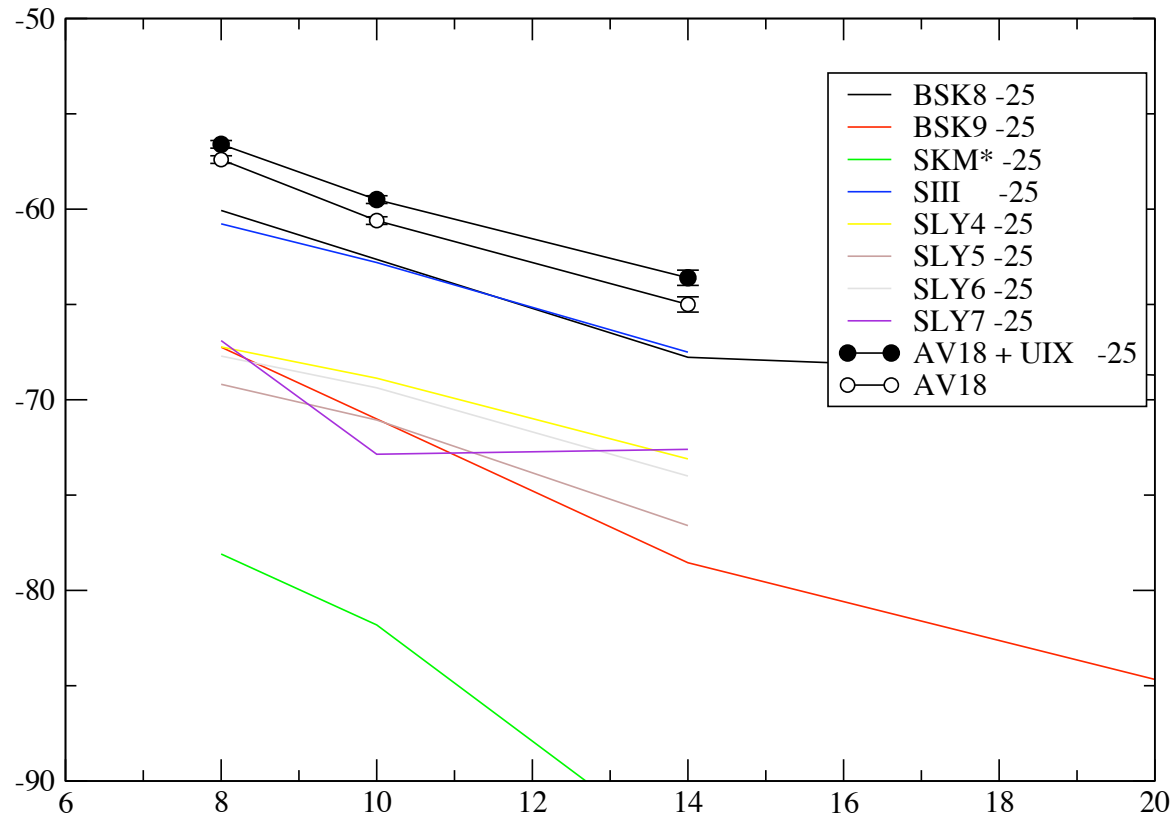
Neutron Drops

Present: Compare ab-initio with Skyrme Models
Future: Additional Constraints to Skyrme,...



Shallow well comparison

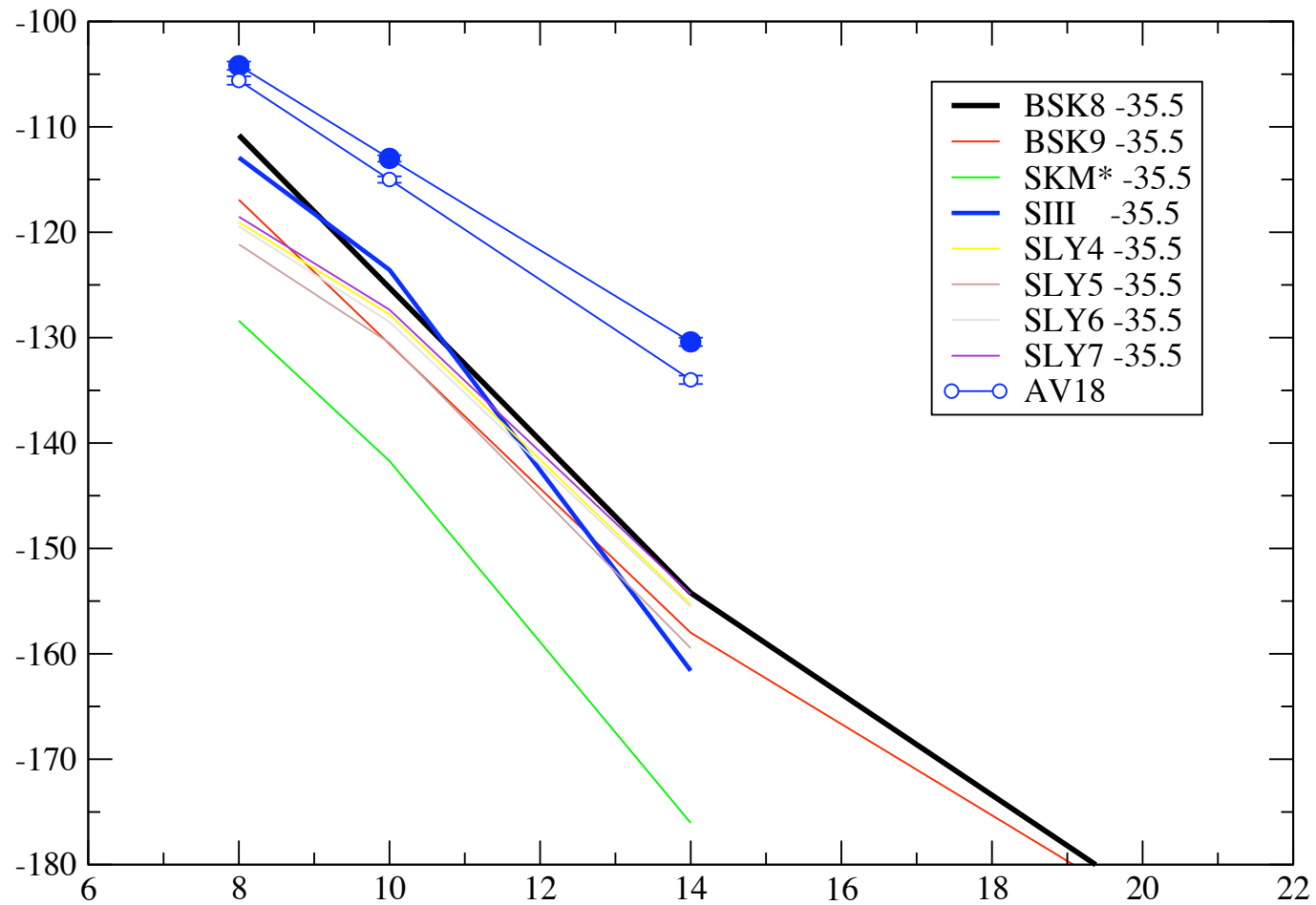
$V_0 = -25$ MeV, ~ 1 MeV/N binding of sd shell



Overbinding, BSK8 and SIII give best agreement

Note: no pairing included in Skyrme

Deeper well comparison

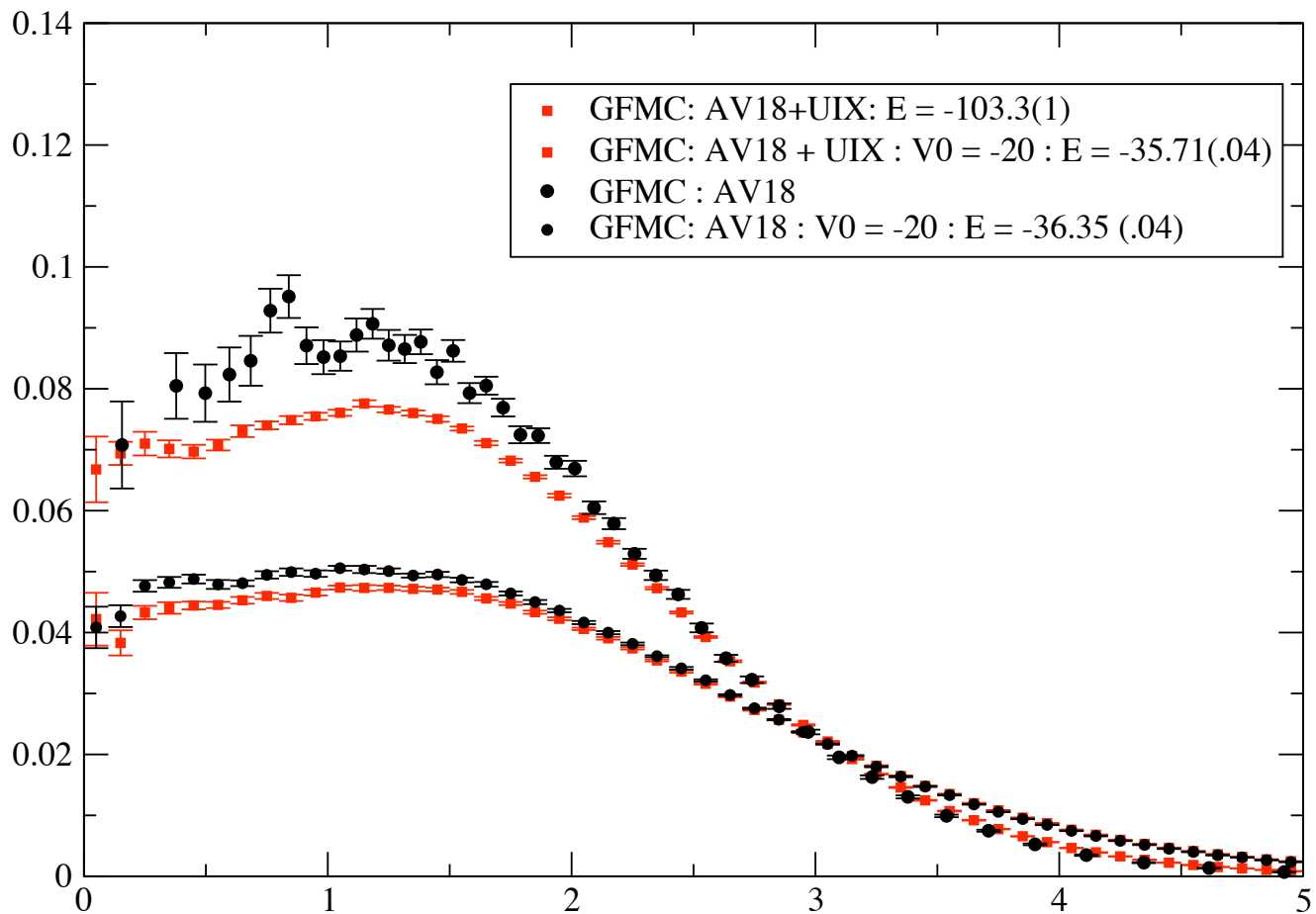


Significant overbinding, particularly for $N > 8$

Single-Particle Densities

8 Neutrons

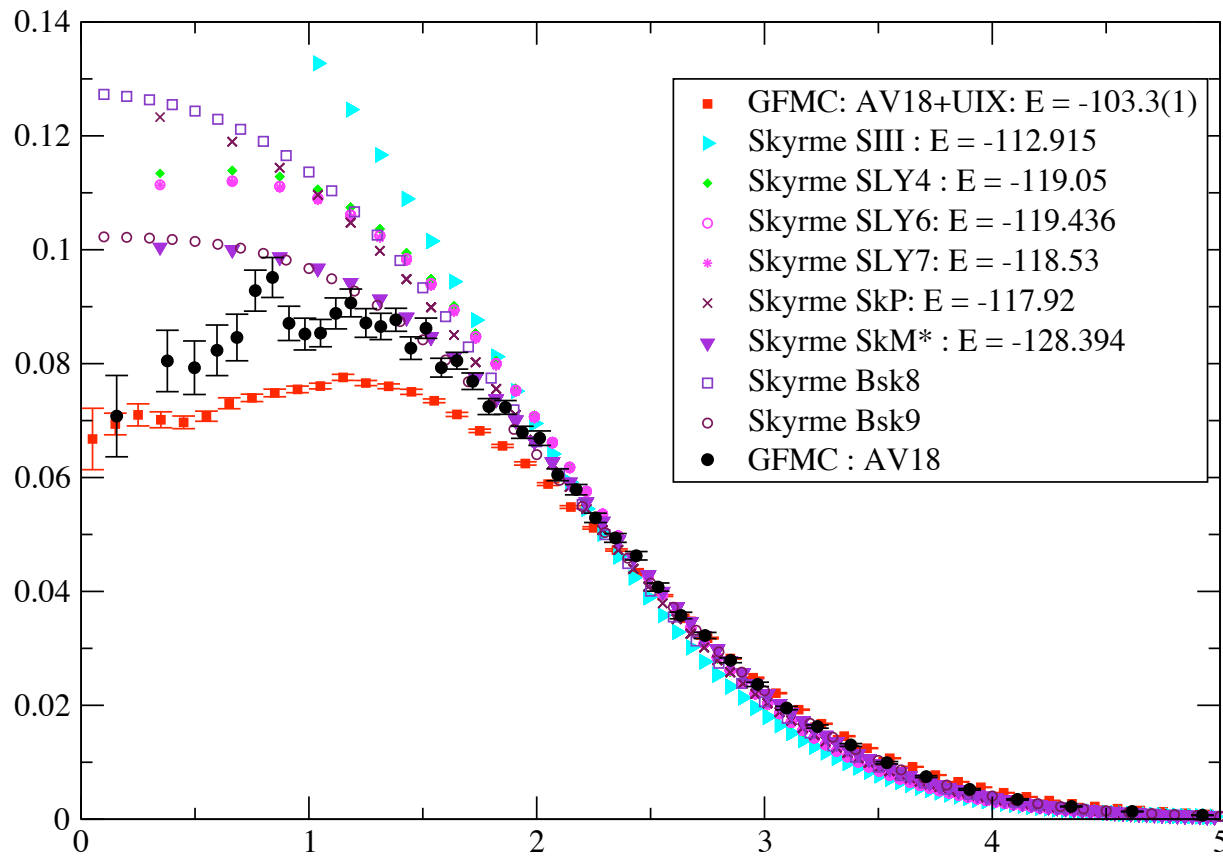
Woods Saxon: $V_0 = -35.5$, $r_0 = 3.0$, $a = 1.1$



Single-Particle Densities

8 Neutrons

Woods Saxon: $V_0 = -35.5$, $r_0 = 3.0$, $a = 1.1$



Pairing and single-particle states

Just starting in Skyrme models

Both GFMC and Skyrme give I_s lower than $0d$
in $N=9$ Woods-Saxon wells

Note: $17O$ has opposite behavior

Magnitude of splitting; dependence on well
being investigated

Plans: Remainder of year 2

Neutron Matter: finish s.p. excitations and comparisons w/ other results

Neutron Drops: finish first round of drops, including pairing and HO pot.

Nuclei: contribute to improving initial I2C

Plans: Year 3

Neutron Matter/Drops: Additional external potentials
quadropole, other fields in drops
static density response in matter

Nuclear Scattering: Benchmark low-energy scattering in $A < 12$

Light Nuclei: External Wells
Improvements in I2C toward Hoyle state

Algorithms: AFDMC / AFMC methods
promising initial results in (polarized) cold atoms Stetcu

(Preliminary) Plans: Years 4 and 5

Quantum Monte Carlo for largest computers
(Roadrunner, BGP, ...)

Scattering/Reactions for Light Nuclei

^{12}C calculations, Hoyle state and transitions

Larger Nuclei and Matter w/ QMC methods
(AFDMC and/or AFMC)