Neutron Matter and Drops

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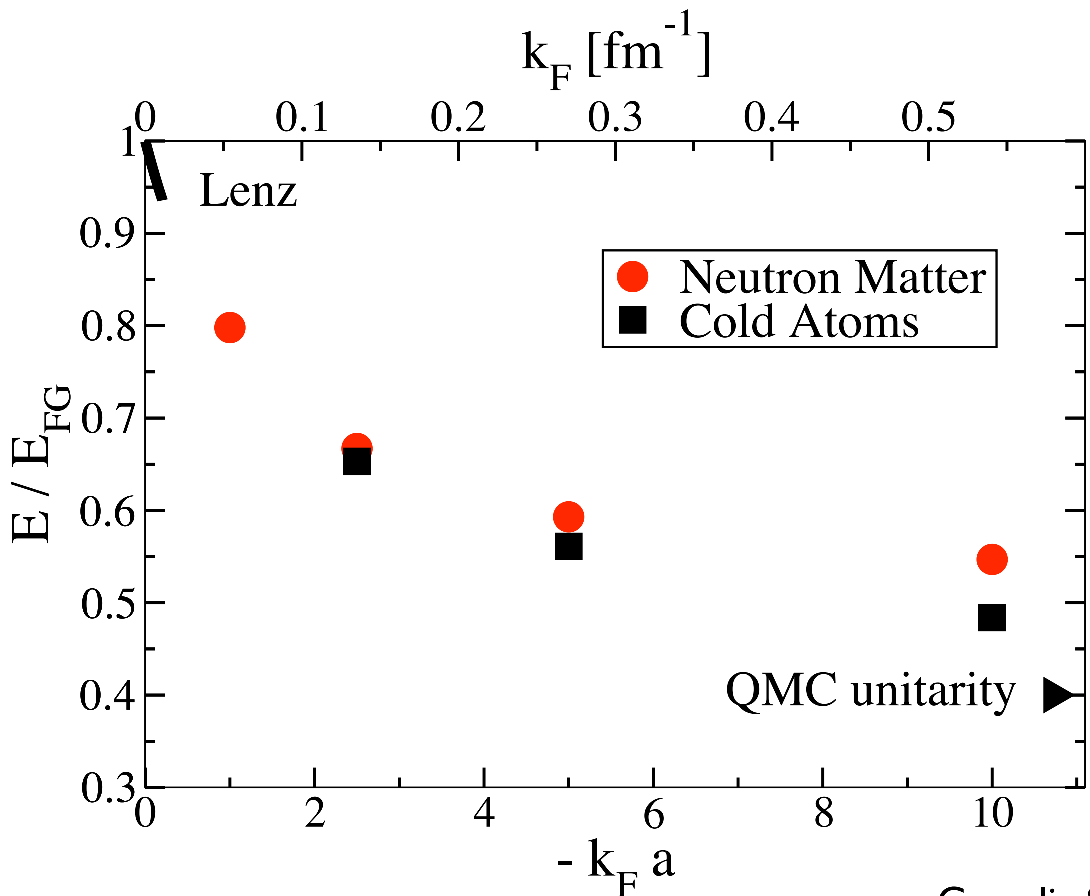
- Neutron Matter
  - EOS
  - Computational Aspects
  - Pairing Gap and Dispersion
  - Other Quantities
- Neutron Drops
  - Energies and Saturation
  - Comparing ab-initio energies with Skyrme
  - Pairing and Single-Particle Energies
- Future

Neutron Matter EOS

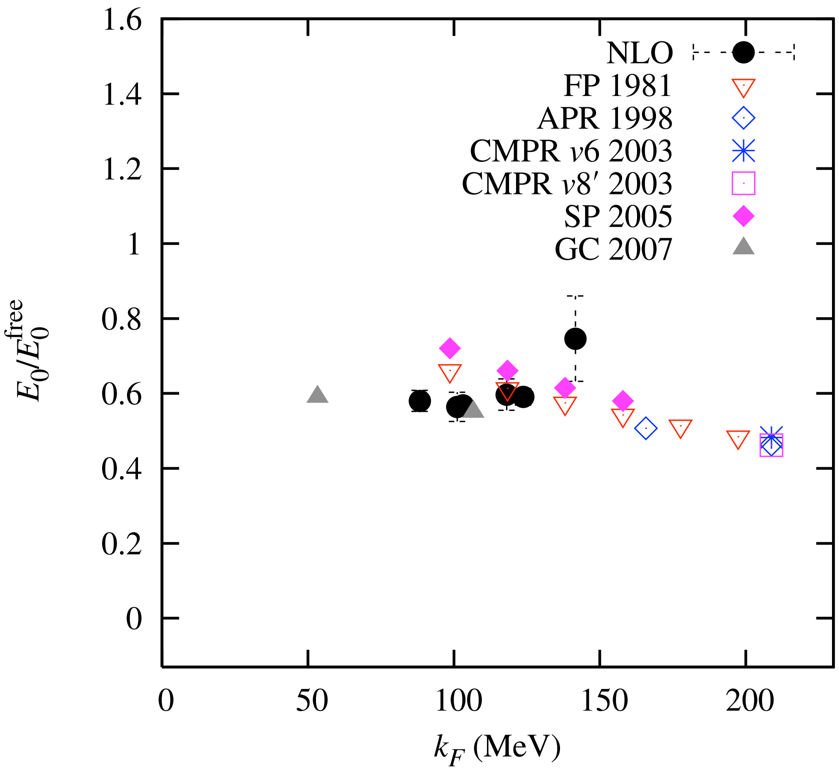
Neutron Matter properties less well-known than Nuclear Matter near equilibrium density
Ab Initio calculations can provide guidance to the density functional

Equation of State at Low Densities



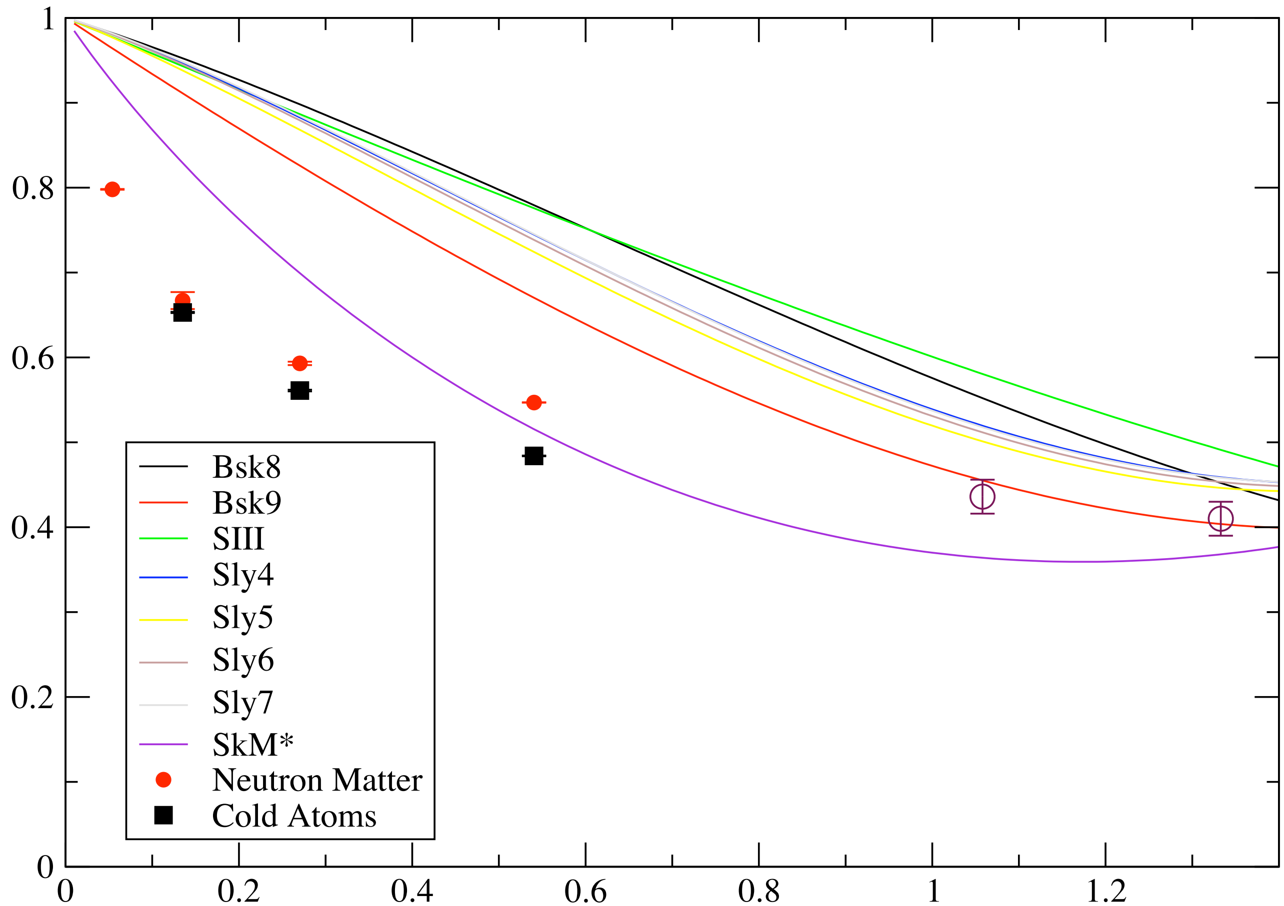
Gezerlis & Carlson, PRC 2008

Dilute Neutron Matter
various simulations



Dean Lee (08)

Low Density Neutron Matter
Microscopic vs. Skyrme



Computational Approach:

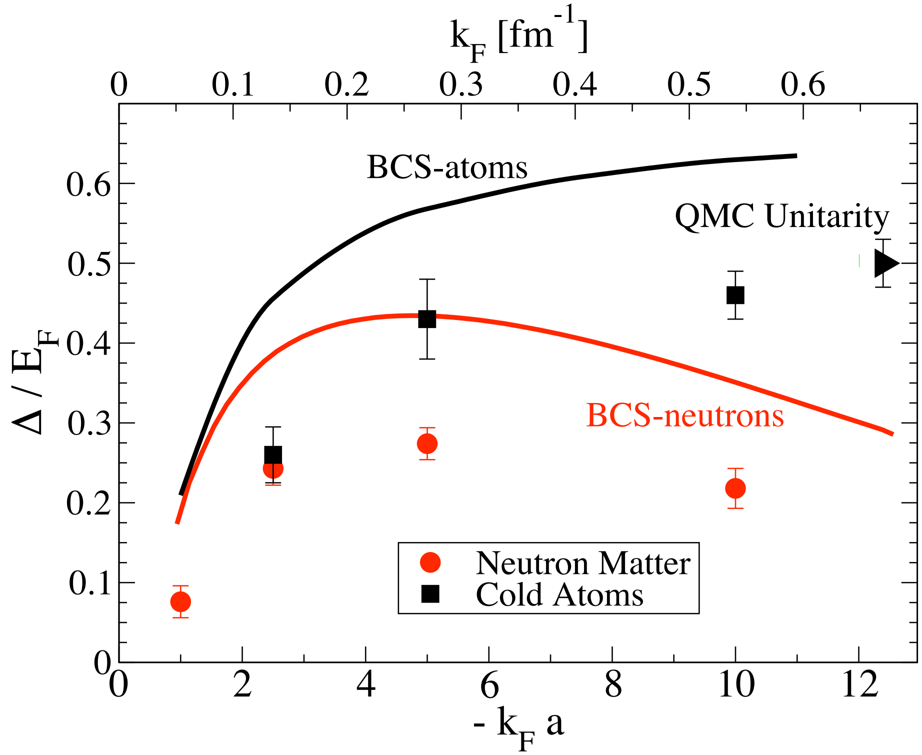
GFMC: sum over spin/isospin explicitly
Diffusion MC: spin-independent (s-wave interactions)
AFDMC: Monte-Carlo sums over spin/isospin

All algorithms are branching random walks:
Significant linear algebra at each step in the walk

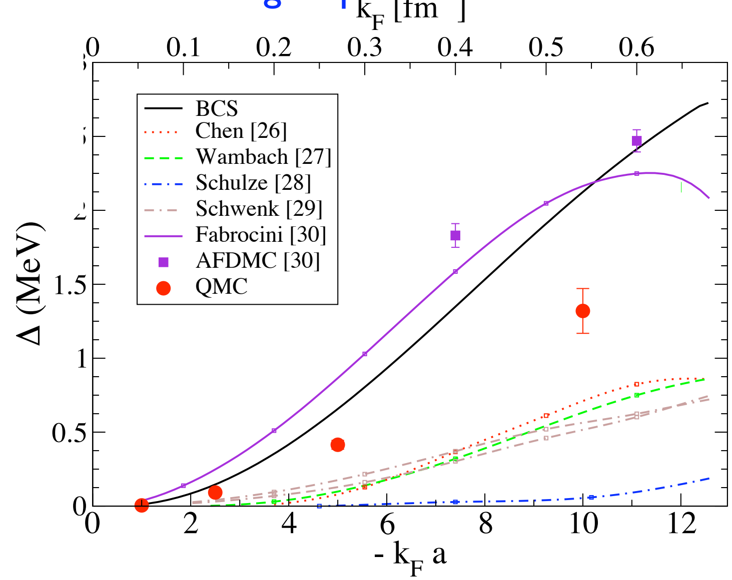
Neutron Matter Diffusion Monte Carlo
~65 particles (scales like N^3)
Gap with even/odd staggering
Need << 1 MeV accuracy

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

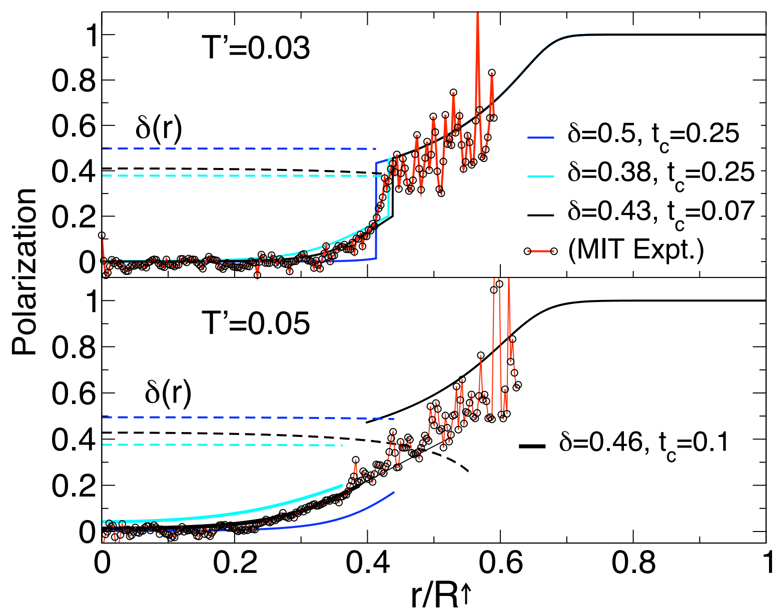


Pairing Gap at Low Densities



Gezerlis and Carlson, PRC 08

Neutron Matter Pairing Gap

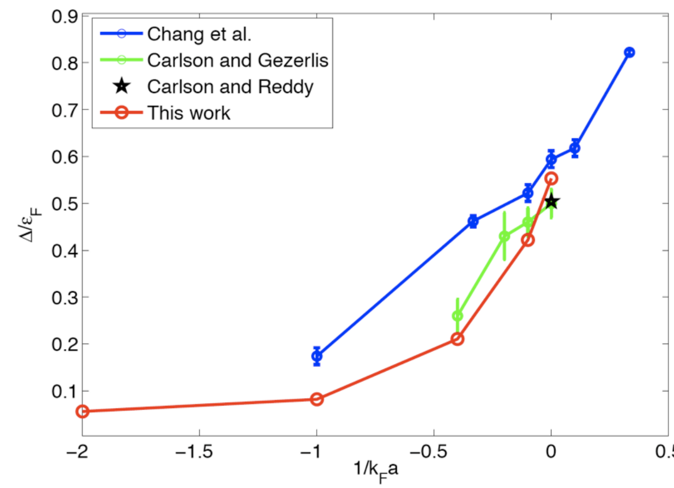


Analysis of cold atom experiments gives Gap/Ef = 0.45 (05).

Largest Gap/Ef in any system!

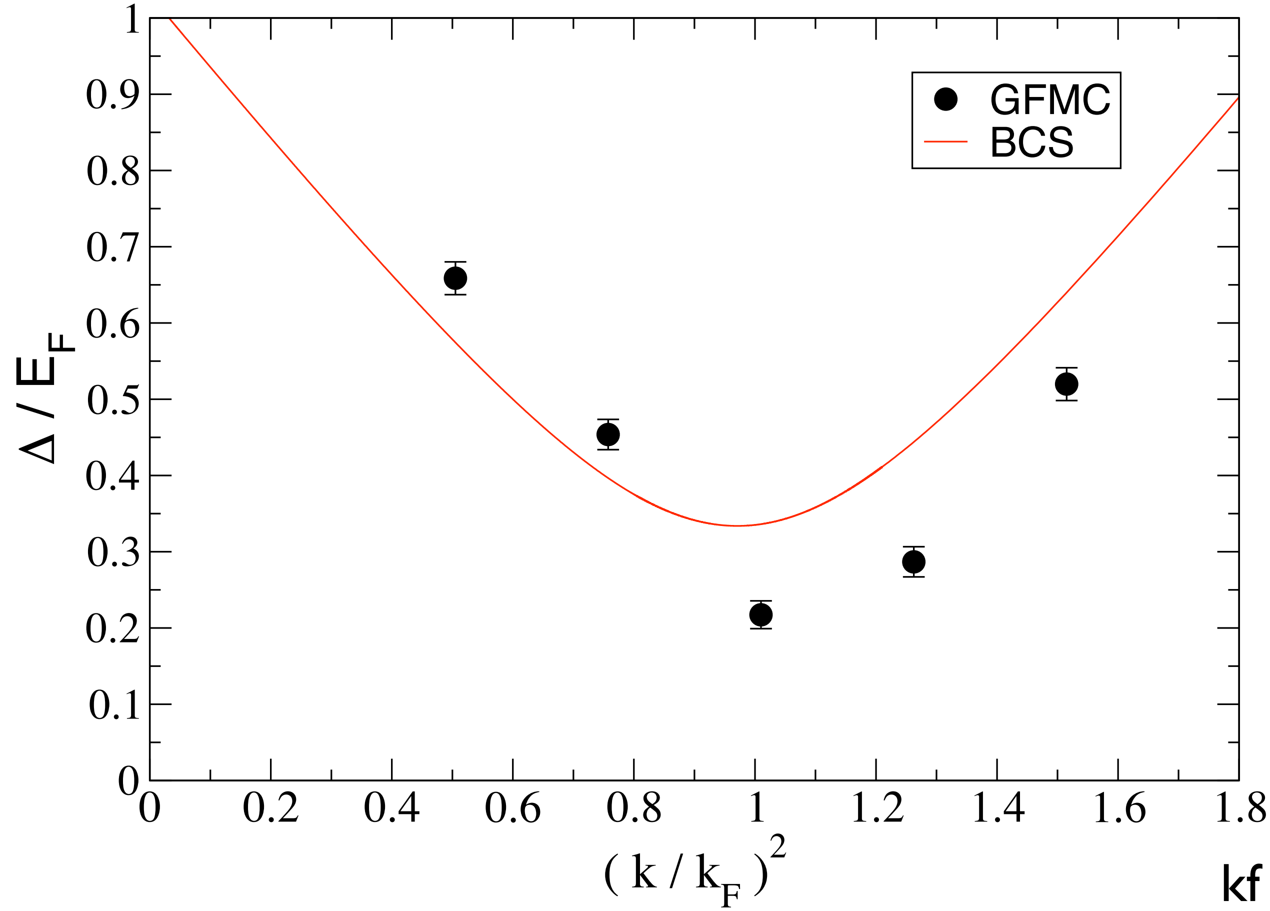
Carlson and Reddy, PRL 08

Pairing Gap for Atomic Gas
Experimentally confirmed to ~10%



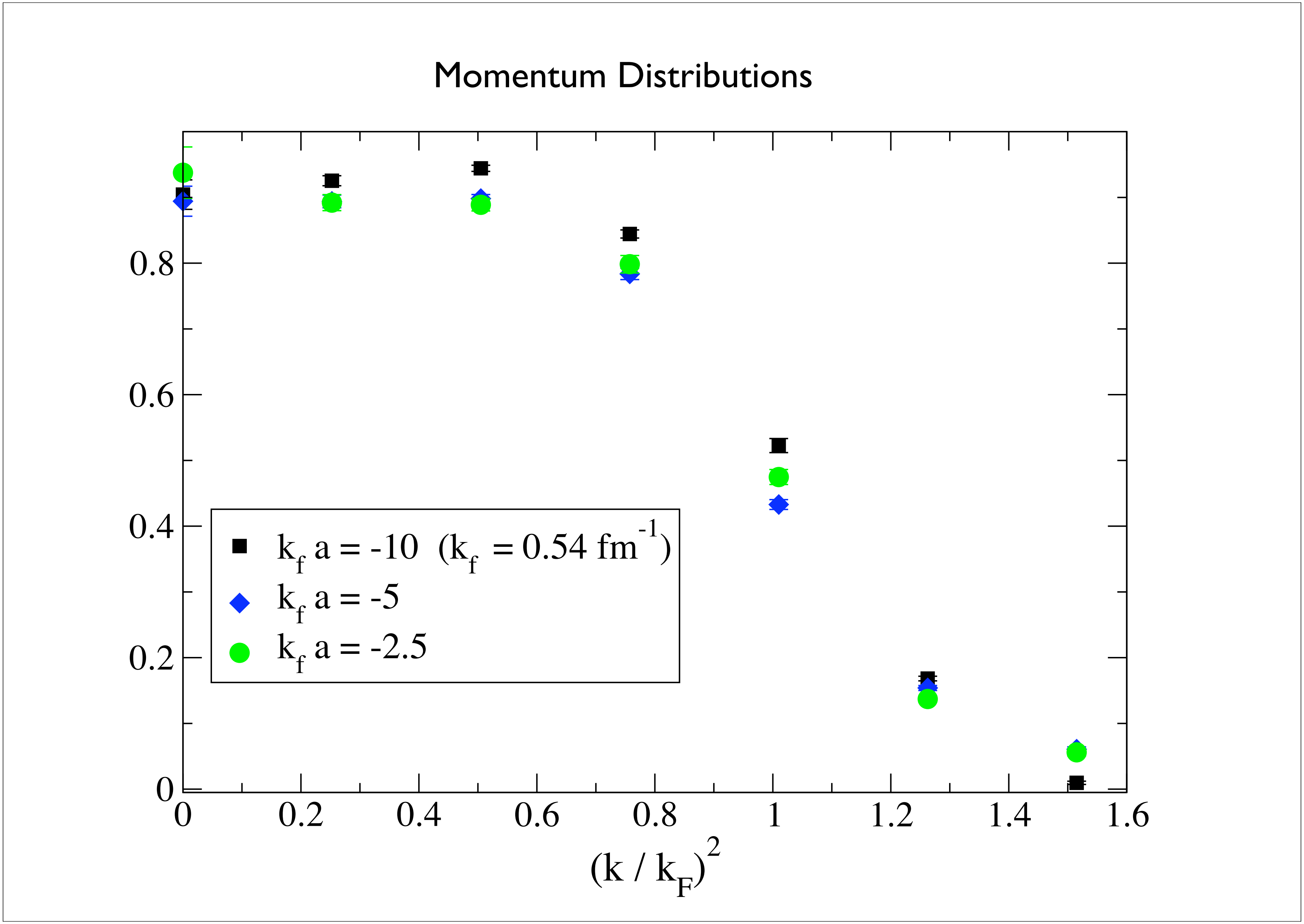
Calculations also agree; new AFDMC calculation much closer to DMC

New Calculations:
Dispersion of Single-Particle States



$k_f\, a = -10$

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

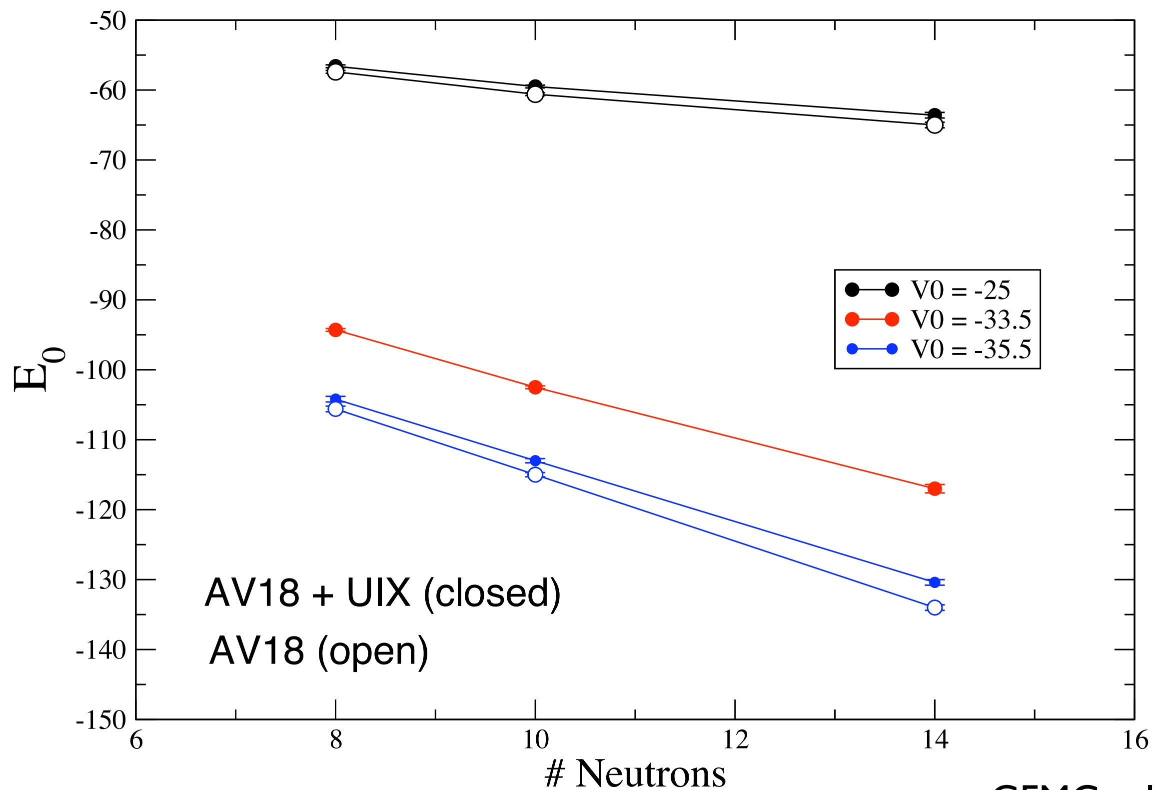

Momentum Distributions
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
(k / k_F)^2
k_f a = -10 (k_f = 0.54 fm^-1)
k_f a = -5
k_f a = -2.5

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

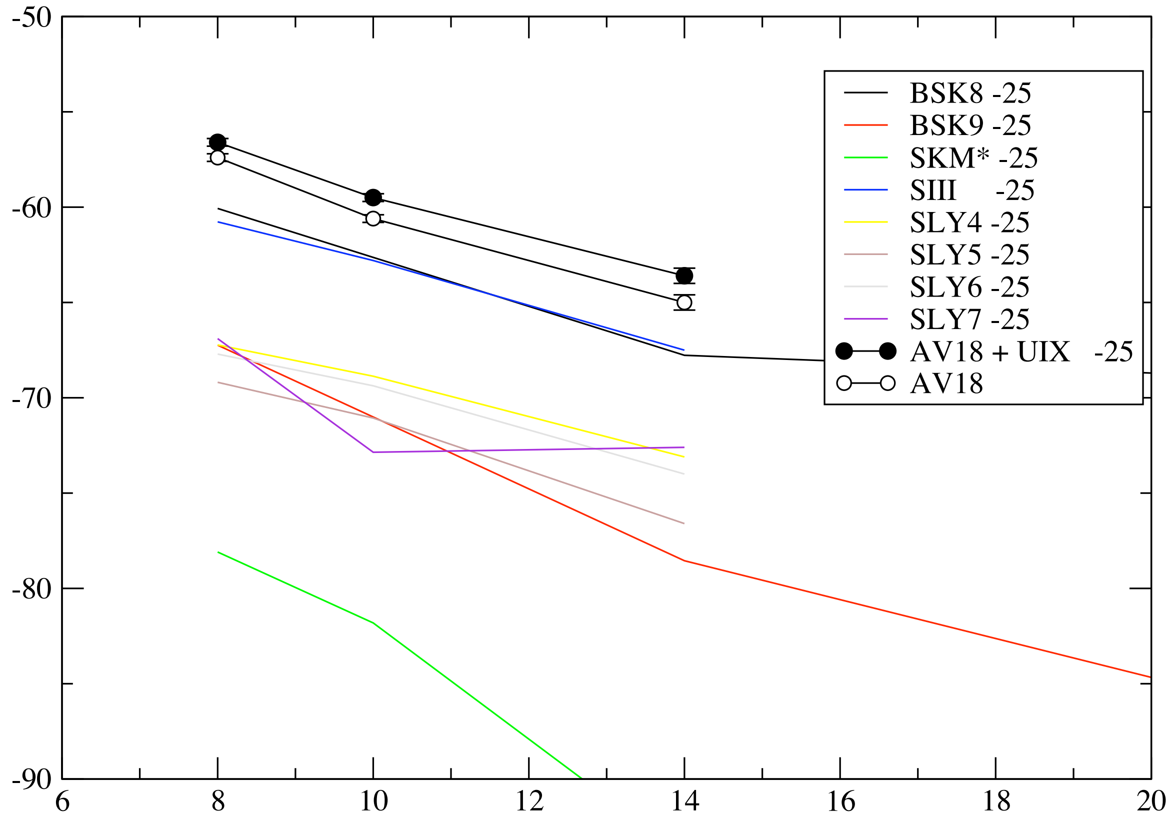
Present: Compare ab-initio with Skyrme Models
Future: Additional Constraints to Skyrme,...



GFMC calculations

Shallow well comparison

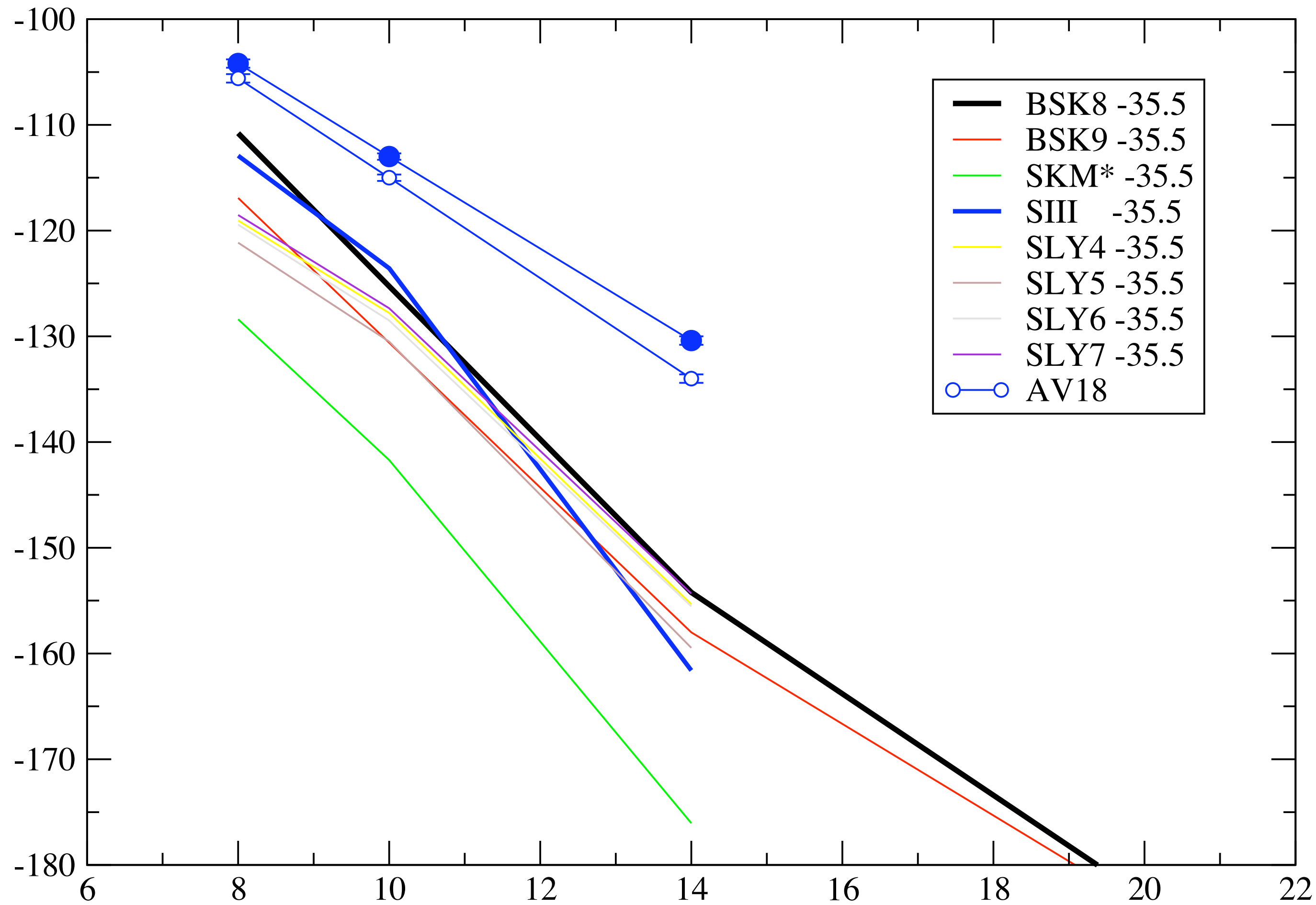
V0 = -25 MeV, ~ 1 MeV/N binding of sd shell



Overbinding, BSK8 and SIII give best agreement

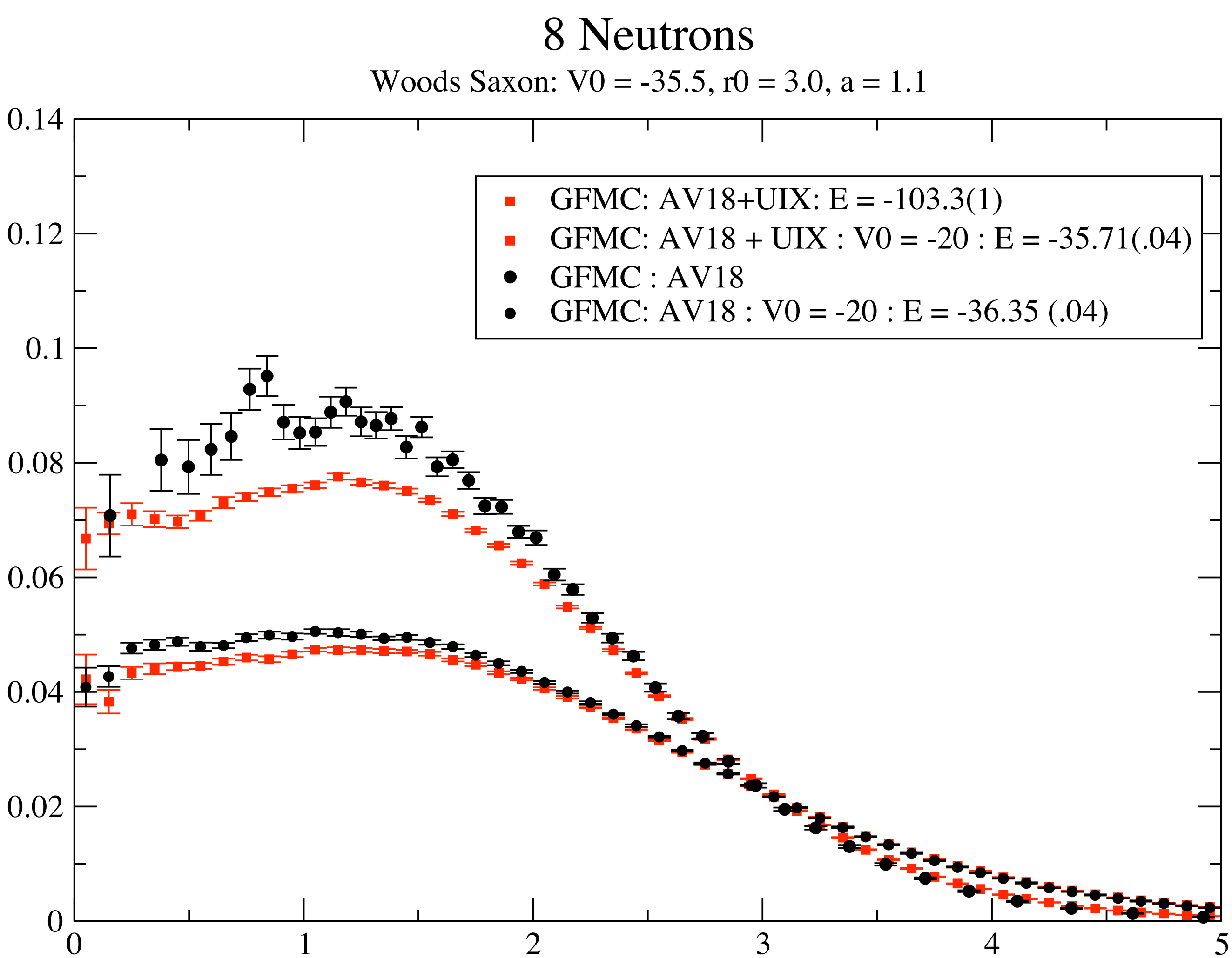
Note: no pairing included in Skyrme

Deeper well comparison

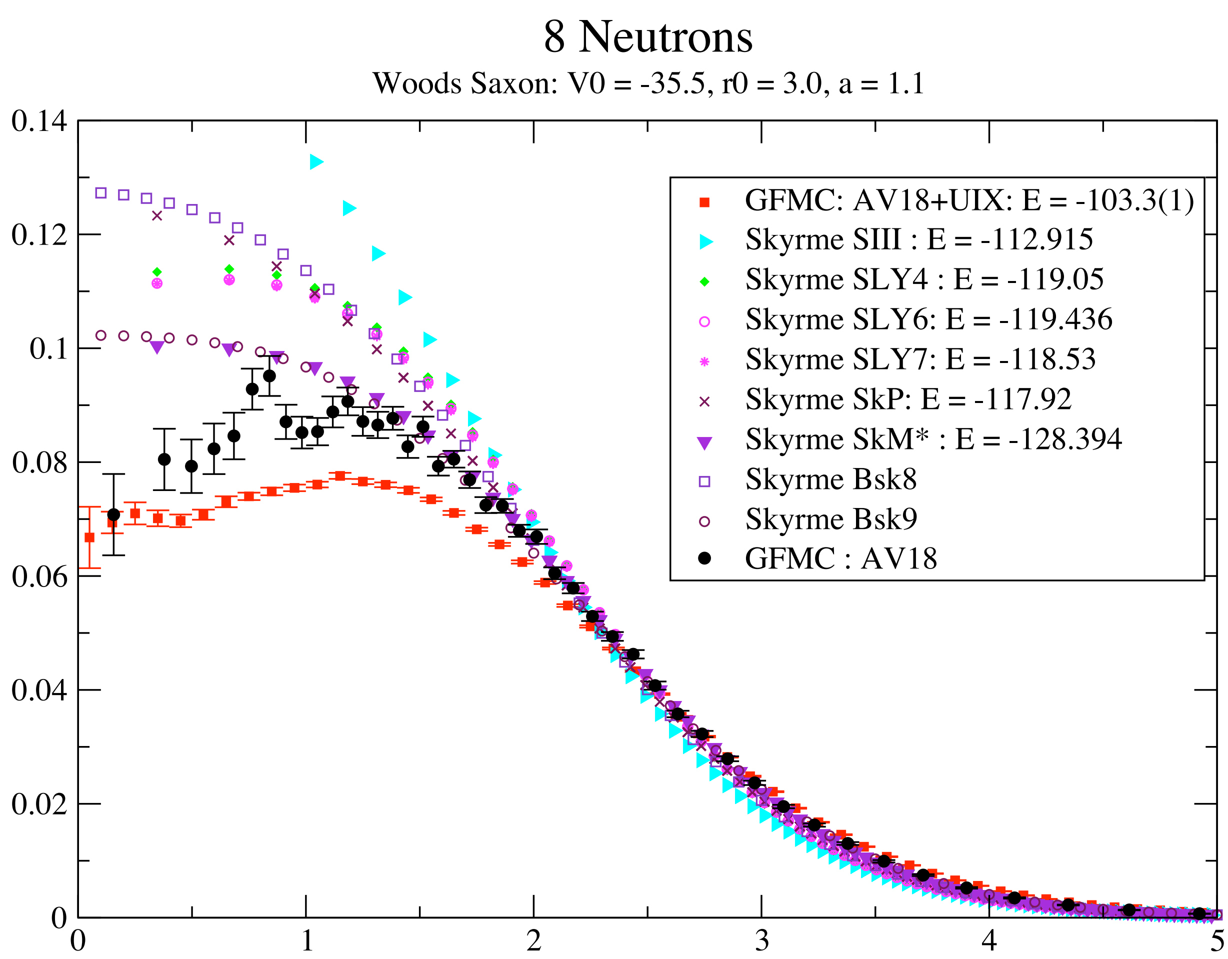


Significant overbinding, particularly for N>8

Single-Particle Densities



Single-Particle Densities



Pairing and single-particle states

Just starting in Skyrme models

Both GFMC and Skyrme give 1s 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 12C

Plans: Year 3

Neutron Matter/Drops: Additional external potentials
quadrupole, other fields in drops
static density response in matter
Nuclear Scattering: Benchmark low-energy scattering in A<12
Light Nuclei: External Wells
Improvements in 12C 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

12C calculations, Hoyle state and transitions

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