MB31 - TIFPA

Diego Lonardoni (studente Ph.D.)
Alessandro Roggero (studente Ph.D.)
Lorenzo Contessi (laureando LM)
Francesco Catalano (laureando LM)
[José Maria Escartin Esteban (post-doc INFN)]
[Abhishek Mukherjee (post-doc ECT*)]
Leonardo Colletti (ins. s.m.s.)
Enrico Lipparini (ass. senior)
Francesco Pederiva

TIFPA = Trento Institute for Fundamental Physics & Applications

A Trento un nuovo centro di fisica delle particelle

Studi di fotonica, supercalcolo e biomedicina

ANSA - 15 gennaio, 18:41

La fisica delle particelle e le sue applicazioni nello sviluppo di tecnologie d'avanguardia nei settori della fotonica, della ricerca spaziale, del supercalcolo e della biomedicina saranno al centro delle attività di ricerca del Trento Institute for Fundamental Physics and Application (Tifpa), il nuovo centro dell'Istituto Nazionale di Fisica Nucleare (Infn), inaugurato oggi alla presenza del ministro dell'Università e della Ricerca, Francesco Profumo.

Nato dalla collaborazione tra Infn, università di Trento, Fondazione Bruno Kessler e Agenzia provinciale di Trento per la Protonterapia (ATreP), che hanno firmato oggi una dichiarazione d'intenti, il nuovo centro avrà sede a Povo, sulla collina di Trento, presso il dipartimento di Fisica. Una settantina i ricercatori coinvolti.
Il ministro Profumo ha sottolineato "l'importanza strategica di questa nuova apertura sia per le potenzialità di sviluppo dal punto di vista scientifico, sia sul versante della sinergia tra istituzioni".

Per il presidente dell'Infn, Fernando Ferroni, "in un momento così difficile per il Paese il Tifpa rappresenta una scelta di eccellenza scientifica e di innovazione". Una struttura come questa, ha aggiunto, "promuoverà anche il trasferimento della conoscenza alla società e avrà la capacità di attrarre finanziamenti europei".

Il nuovo centro svolgerà ricerche sia nell'ambito della fisica di base, sia in quelli dell'innovazione e del trasferimento tecnologico, sfruttando infrastrutture, competenze e risorse umane già esistenti presso gli enti trentini partecipanti e potenziando specifici settori di intervento. Il centro potrà contare, ad esempio, sulle infrastrutture del Centro Materiali e Microsistemi e del Centro Europeo di Fisica Teorica della Fondazione Bruno Kessler e anche sulla nuova macchina per la protonterapia medica che entrerà in funzione entro la fine del 2013.

Research lines

- Equation of state of dense nuclear matter - Neutron star cores - Effective interactions
- Response functions
- Development of Quantum Monte Carlo methods

Equation of state

DIEGO's talk

- We are currently focusing on the EoS in presence of hyperons.

- Strategy:

➡ Use available data on Λ-hypernuclei to gauge the ΛN and ΛNN interaction.

➡ Employ this (realistic) model potential in a microscopic determination of the EoS of PNM+Λ

➡ Extend calculations to Σ^- : the level of accuracy will be affected by the availability of data.

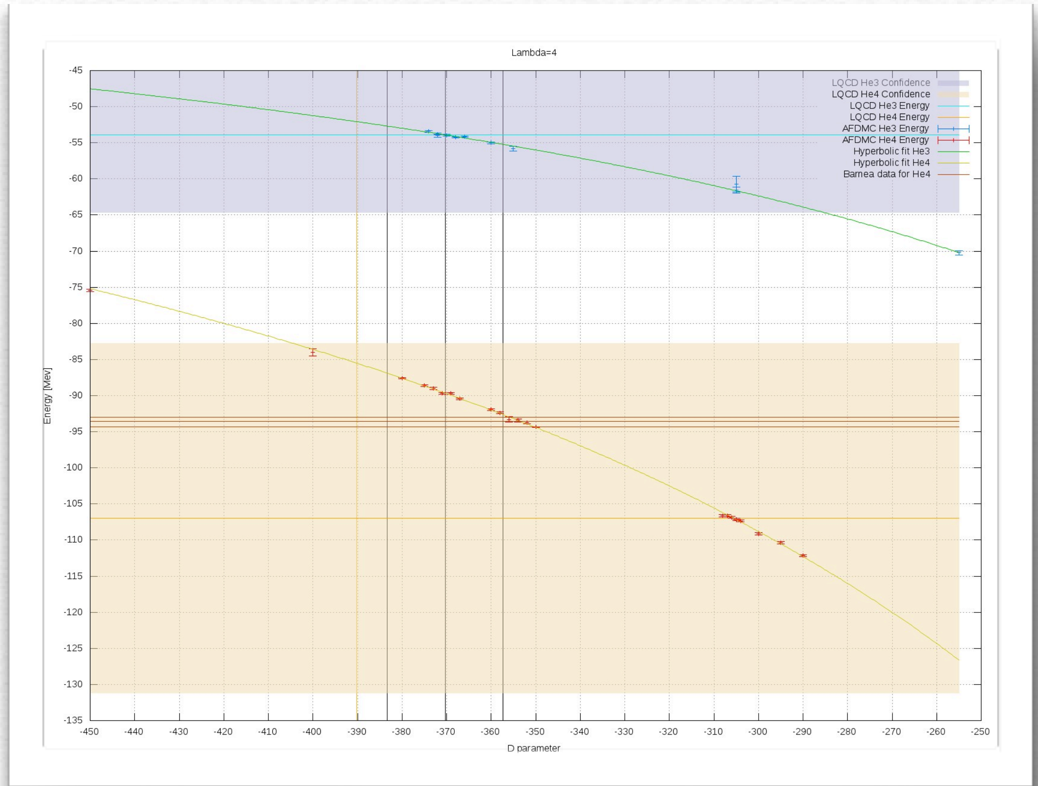
➡ Compute the full EoS (p,n,Λ, Σ^-,e,μ)

Effective π-less theories

Lorenzo Contessi, FP, Nir Barnea, U. van Kolck

Plan: build a π-less effective Hamiltonian in coordinate space on few-body system and check the results for nuclei with larger masses.

Test: a nuclear physics with m_π=800MeV - LQCD calculations available for A=3,4



$$V_{LO} = C_1^{LO} + C_2^{LO}\sigma_1 \cdot \sigma_2 \quad V_{LO}^{3b} = D_1 \tau_1 \cdot \tau_2$$

	Λ	D	ΔD
He3	6	-1069,2	315,2
He3	4	-370,2	116,3
He3	2	-72,3	32,1

Regularization in r space

$$V_{LO}(r) = (C_1^{LO} + C_2^{LO}\sigma_1 \cdot \sigma_2) I_0(\Lambda, r)$$

$$I_k(\Lambda, r) = \Lambda^k e^{-\Lambda^2 r^2/4}$$

Calculations with AFDMC ok

Finite temperature EoS

T=0 calculations from AFDMC and Free energy from FHNC

A. Mukherjee, FP, S. Gandolfi, J. Carlson

- Last similar calculation was done > 3 decades ago: Friedman & Pandharipande, Nucl. Phys. A (1981) --> bestseller (> 600 citations) but never incorporated in supernovae codes

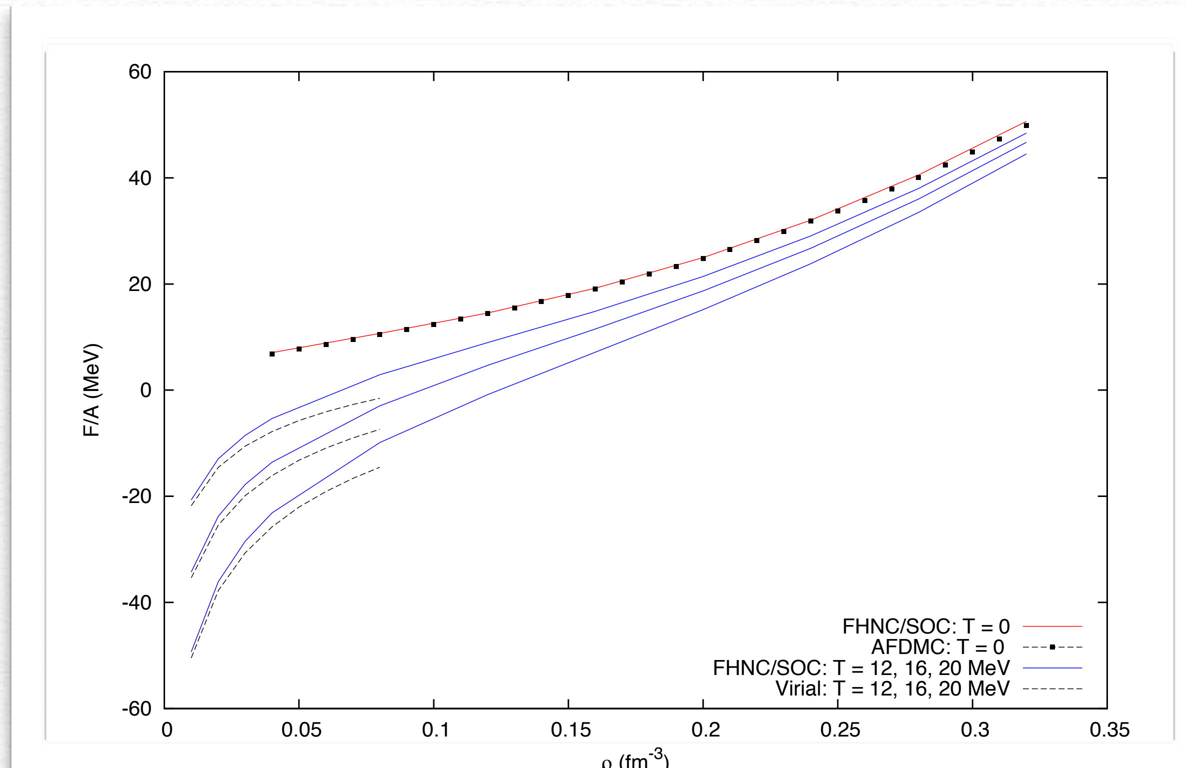
- What is new this time?

1) FHNC shown to be rigorous at finite T; no orthogonality corrections: Mukherjee & Pandharipande, PRC (2007)
2)'Better' interactions: FP used older models
3) Pair correlation operator calculated at every T : Mukherjee, PRC (2009)

Realistic EoS for Supernovae matter

Current simulations use Lattimer-Swesty or Shen et. al
No connection with NN interactions

We need:
* Realistic NN interactions (AV8' + UIX)
* A reliable many body technique (FHNC/SOC)



Finite temperature EoS

Most importantly we ensure that FHNC/SOC agrees with the best known calculations in the limiting cases:

- with AFDMC at T = 0 : Gandolfi et al, PRC (2009) --> extremely non-trivial

- with Virial EoS at large T and small rho : Horowitz & Schwenk, Phys. Lett. B (2006) --> expected

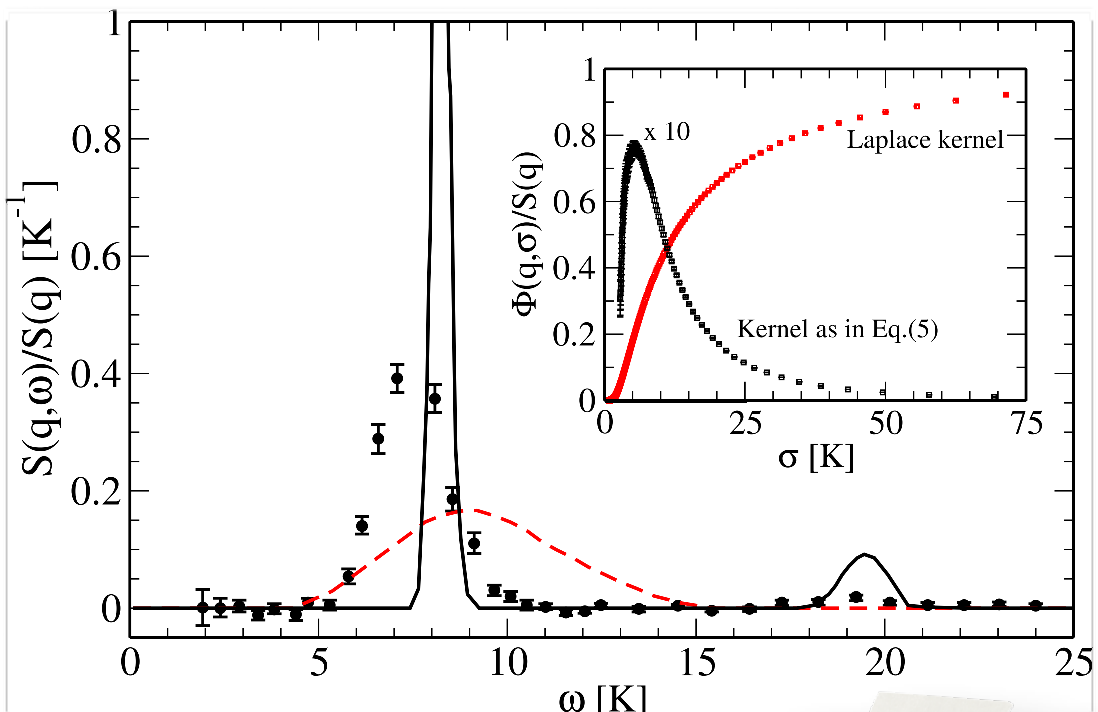
PERSPECTIVES

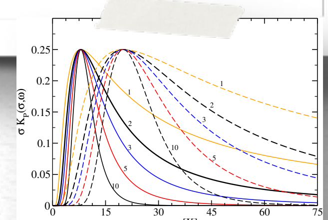
- In the long term, we expect to produce something which can be plugged into supernovae codes
- First step: neutron matter --> AFDMC is expected to work best here.

Response functions

From QMC calculations

A. Roggero, FP, with G. Orlandini and W. Leidemann





$$S_{\hat{O}}(\mathbf{q},\omega) = \sum_\nu |\langle \Psi_\nu | \hat{O}(\mathbf{q}) | \Psi_0 \rangle|^2 \delta(E_\nu - \omega)$$

$$= \langle \Psi_0 | \hat{O}^\dagger(\mathbf{q}) \delta(\hat{H} - \omega) \hat{O}(\mathbf{q}) | \Psi_0 \rangle$$

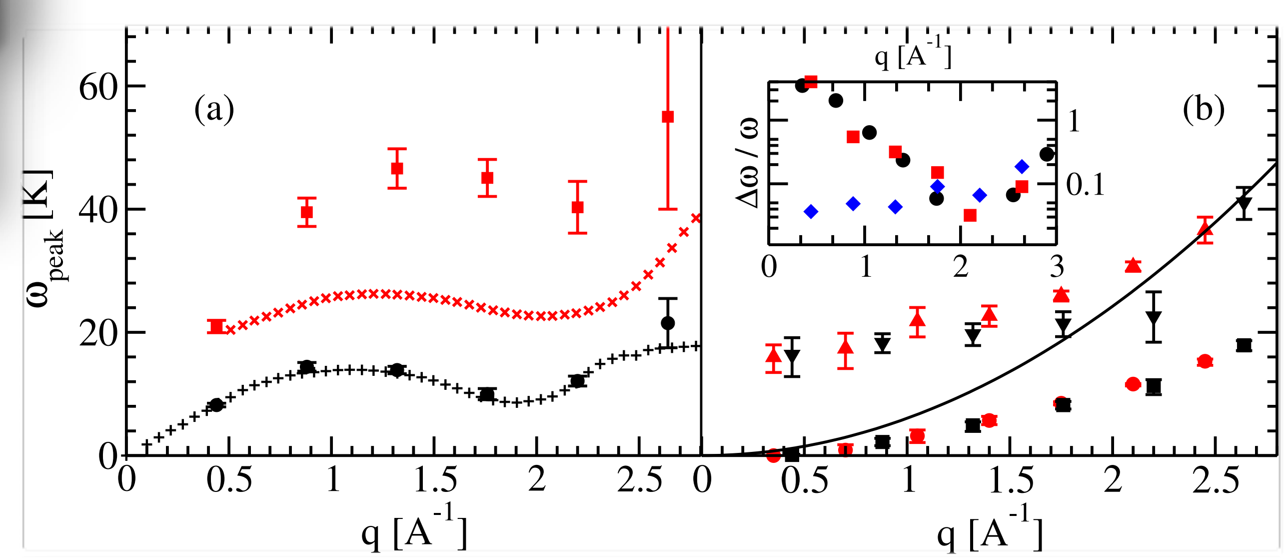
$$\Phi(\mathbf{q},\sigma) = \int K(\sigma,\omega)\, S_{\hat{O}}(\mathbf{q},\omega)\, d\omega .$$

The natural choice within QMC is a Laplace kernel, very inefficient and amplifying the ill-posedness of the inversion problem.

Better kernel: SUMUDU

$$K_P(\sigma,\omega) = N \left[\frac{e^{-\mu\frac{\omega}{\sigma}}}{\sigma} - \frac{e^{-\nu\frac{\omega}{\sigma}}}{\sigma} \right]^P$$

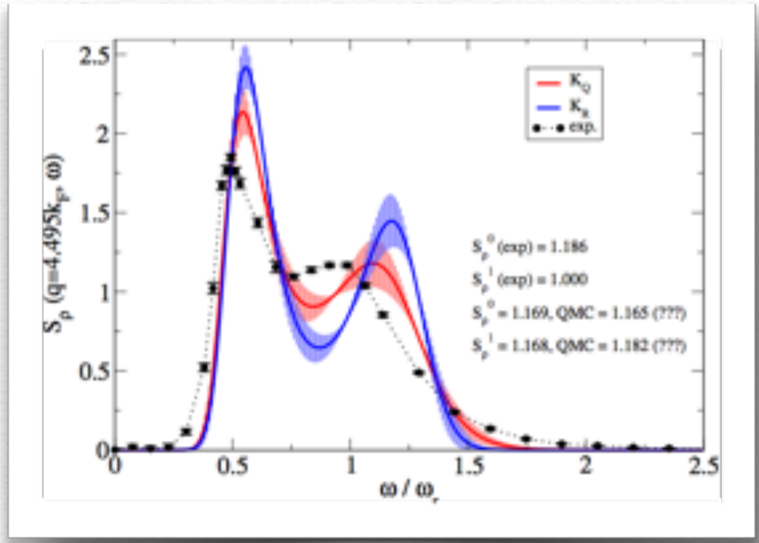
- Still "natural" in the language of QMC
- "Bell shaped", and therefore more efficient and less prone to inversion ambiguities.

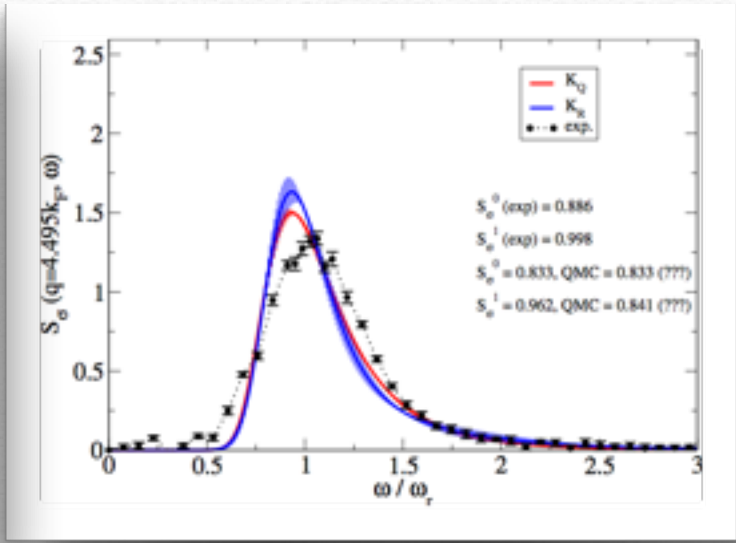


Response functions

ONGOING PROJECTS:

- Extension to the many-Fermion case (with S. Gandolfi and J. Carlson, LLNL)





- Attempt to extend the use of the Sumudu kernel in Path Integral Monte Carlo (T>0) calculations (Jonathan Dubois)

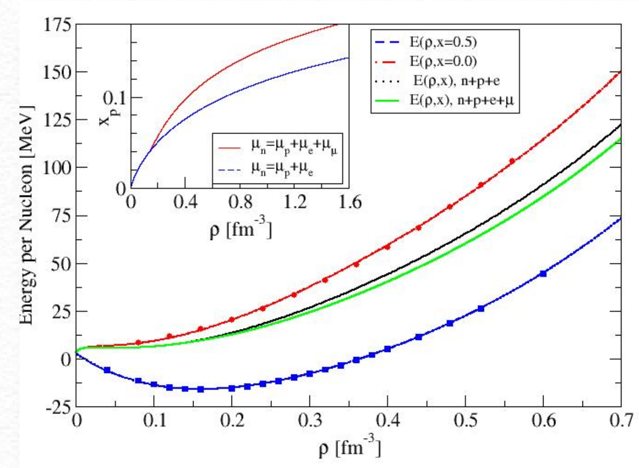
- Use of better kernels within a k space formulation of Diffusion Monte Carlo

Response functions

From TDLIDA calculations

Enrico Lipparini, FP

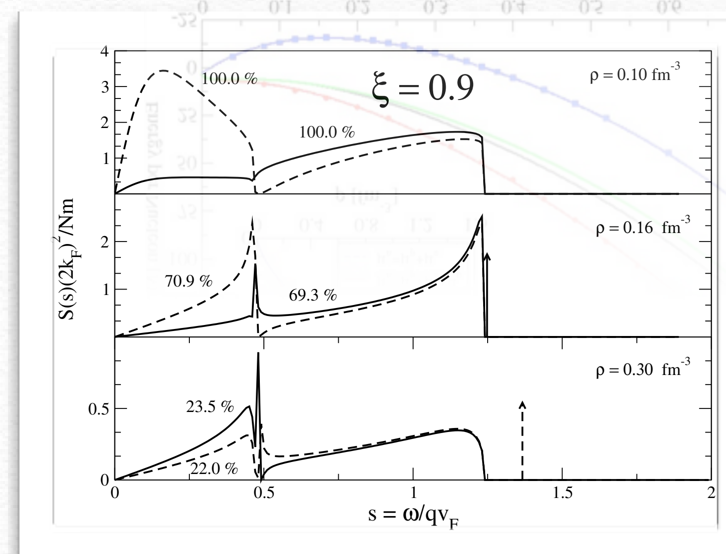
Determined from AFDMC EoS with AV6′+DDP *(Gandolfi et al. 2010)*



$$E(\rho,\xi) = T_0(\rho,\xi) + \int \epsilon_V(\rho,\xi)\ \rho\ d\mathbf{r}$$

$$\epsilon_V(\rho,\xi) = \epsilon_0(\rho) + \xi^2\left[\epsilon_1(\rho) - \epsilon_0(\rho)\right]$$

$$\epsilon_q(\rho) = \epsilon_q^0 + a_q(\rho-\rho_0) + b_q(\rho-\rho_0)^2 + c_q(\rho-\rho_0)^3 e^{\gamma_q(\rho-\rho_0)}$$



$$\chi^s = V\frac{\chi_0^n[V-(V_{p,p}-V_{n,p})\chi_0^p] + \chi_0^p[V-(V_{n,n}-V_{p,n})\chi_0^n]}{(V-V_{p,p}\chi_0^p)(V-V_{n.n}\chi_0^n]) - V_{n,p}\chi_0^n V_{p,n}\chi_0^p}\ ,$$

$$\chi^v = V\frac{\chi_0^n[V-(V_{p,p}+V_{n,p})\chi_0^p] + \chi_0^p[V-(V_{n,n}+V_{p,n})\chi_0^n]}{(V-V_{p,p}\chi_0^p)(V-V_{n,n}\chi_0^n) - V_{n,p}\chi_0^n V_{p,n}\chi_0^p}\ .$$

$$v(\mathbf{r}) = \frac{\partial\rho\epsilon_V[\rho(\mathbf{r}),\xi]}{\partial\rho(\mathbf{r})}$$

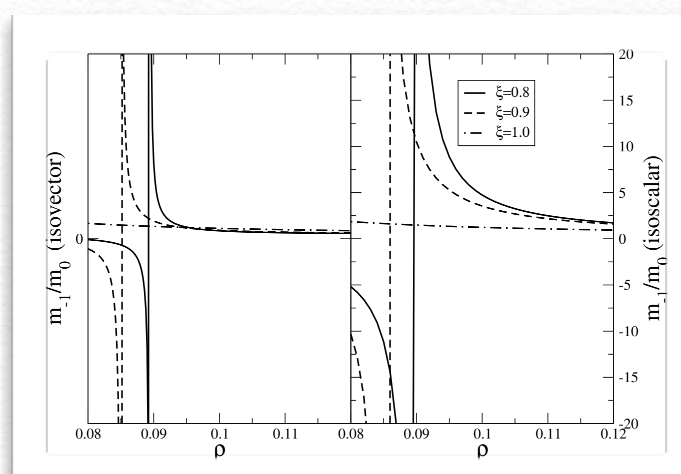
$$w(\mathbf{r}) = \frac{\partial\epsilon_V[\rho(\mathbf{r}),\xi)]}{\partial\xi(\mathbf{r})}$$

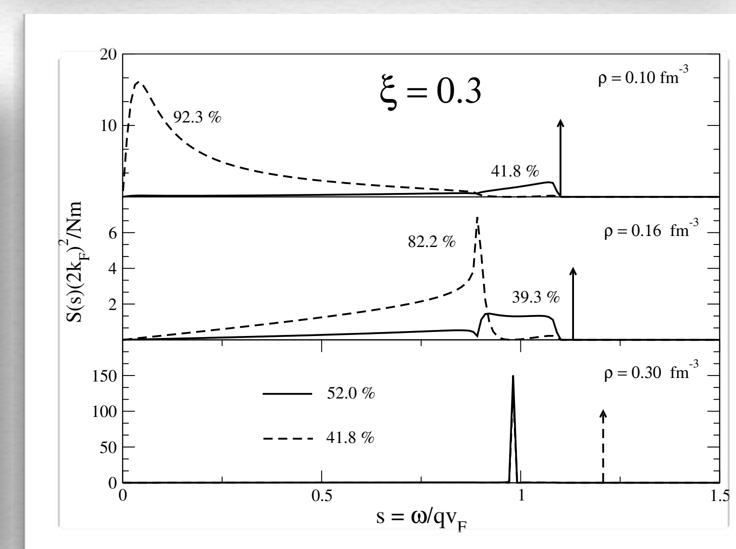
$$V_{nn} = \left.\frac{\partial(v+w)}{\partial\rho_n(\mathbf{r},t)}\right|_{\rho_n,\rho_p} = \left.\left(\frac{\partial}{\partial\rho} + \frac{1}{\rho}\frac{\partial}{\partial\xi}\right)(v+w)\right|_{\rho,\xi},$$

$$V_{np} = \left.\frac{\partial(v+w)}{\partial\rho_p(\mathbf{r},t)}\right|_{\rho_n,\rho_p} = \left.\left(\frac{\partial}{\partial\rho} - \frac{1}{\rho}\frac{\partial}{\partial\xi}\right)(v+w)\right|_{\rho,\xi},$$

$$V_{pn} = \left.\frac{\partial(v-w)}{\partial\rho_n(\mathbf{r},t)}\right|_{\rho_n,\rho_p} = \left.\left(\frac{\partial}{\partial\rho} + \frac{1}{\rho}\frac{\partial}{\partial\xi}\right)(v-w)\right|_{\rho,\xi},$$

$$V_{pp} = \left.\frac{\partial(v-w)}{\partial\rho_p(\mathbf{r},t)}\right|_{\rho_n,\rho_p} = \left.\left(\frac{\partial}{\partial\rho} - \frac{1}{\rho}\frac{\partial}{\partial\xi}\right)(v-w)\right|_{\rho,\xi}.$$





Novel QMC methods

- Diffusion Monte Carlo in k-space with Coupled Cluster importance functions (ALESSANDRO's talk), with A. Mukherjee.
- Refinements of the AFDMC code (S. Gandolfi, K. Schmidt etc...)
- Fermion sign-problem (Mal Kalos): found a long standing problem, looking better now.