Il problema a molti corpi nucleare

Giampaolo Co'

Lecce 22 Aprile 2008

Luca Signorelli, Orvieto (1499-1504)

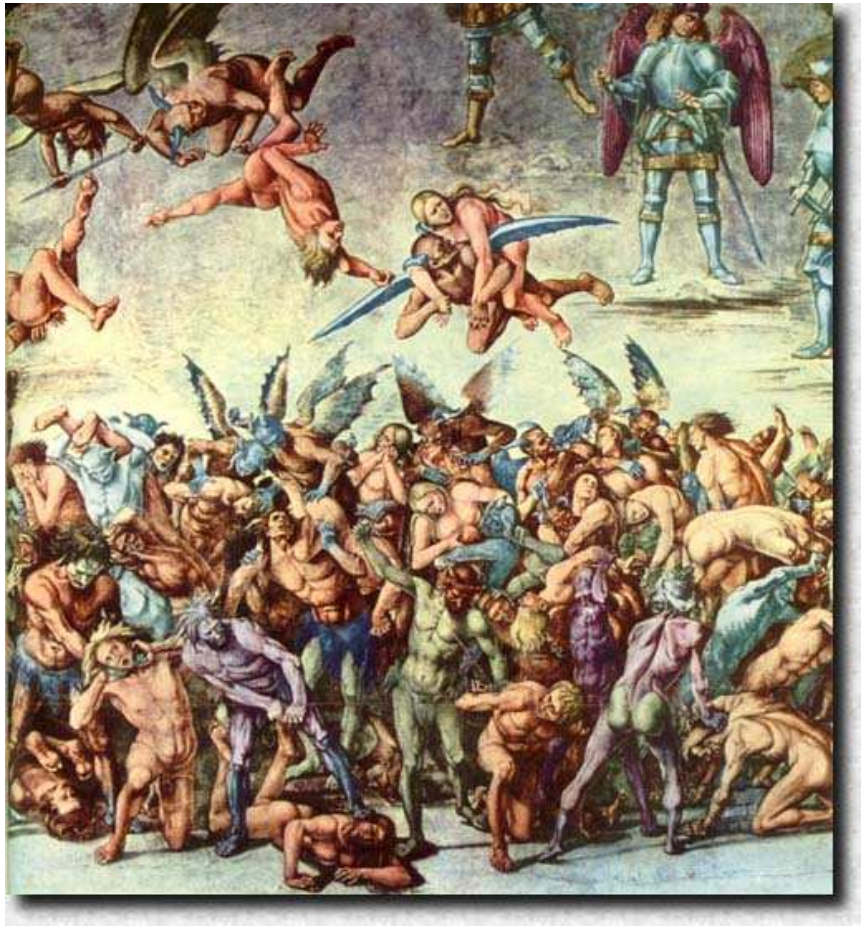
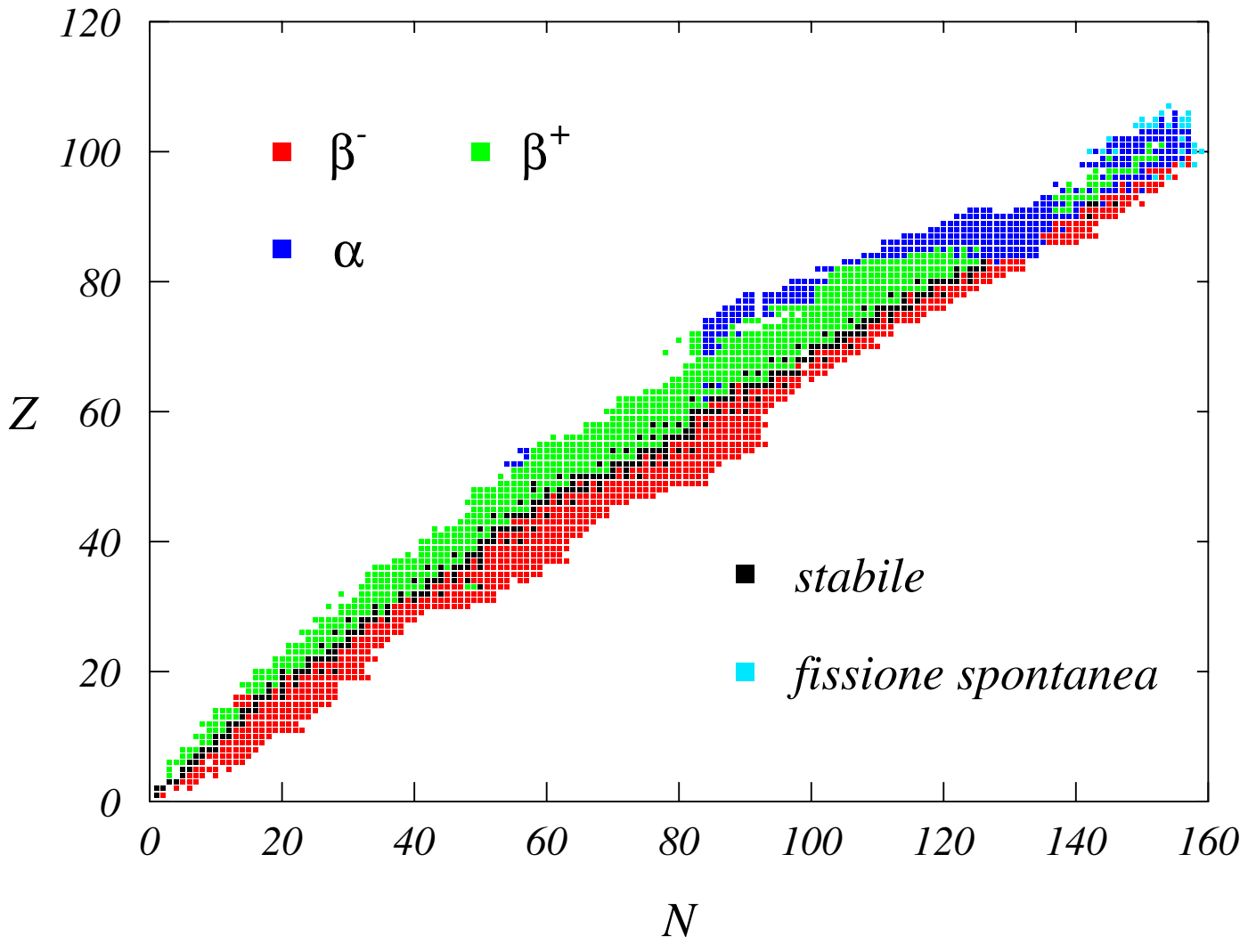


Tavola degli isotopi



Deutone

Il solo sistema legato di due nucleoni

Formato da protone e neutrone

Dipendenza dall'isospin

Deutone

Il solo sistema legato di due nucleoni

Formato da protone e neutrone

Dipendenza dall'isospin

Momento angolare totale J=1

Dipendenza dallo spin

Deutone

Il solo sistema legato di due nucleoni

Formato da protone e neutrone

Dipendenza dall'isospin

Momento angolare totale J=1

Dipendenza dallo spin

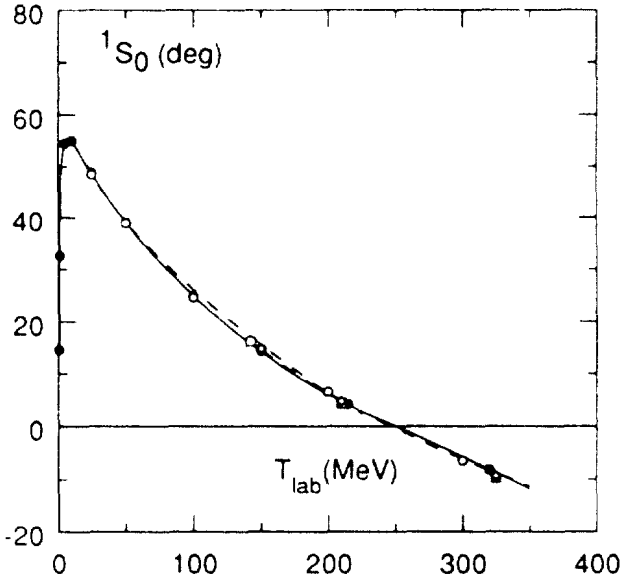
$\mu_d = \mu_p + \mu_n - 0.00222$ magnetoni nucleari
Q=2.82 mb

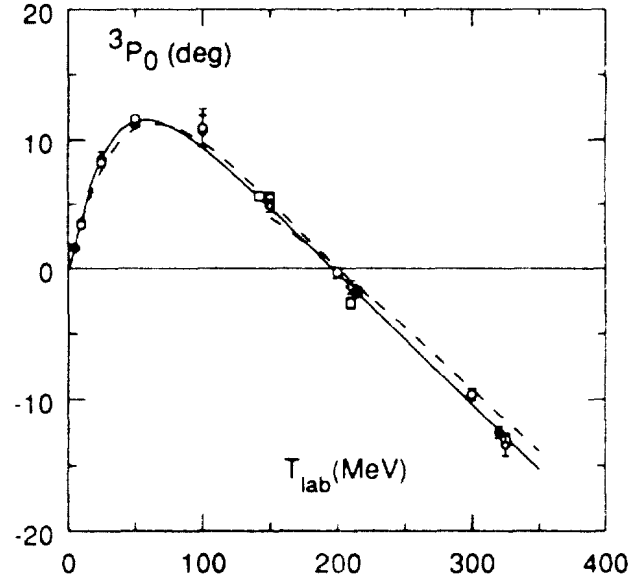
Forze non centrali. Dipendenza dal tensore

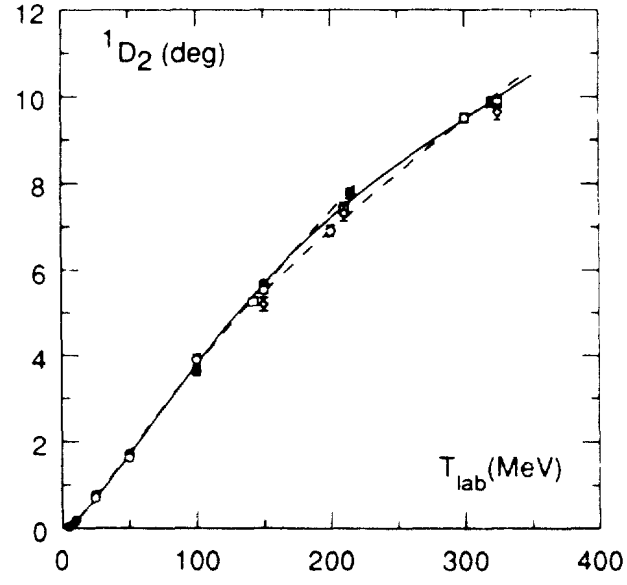
Tensore

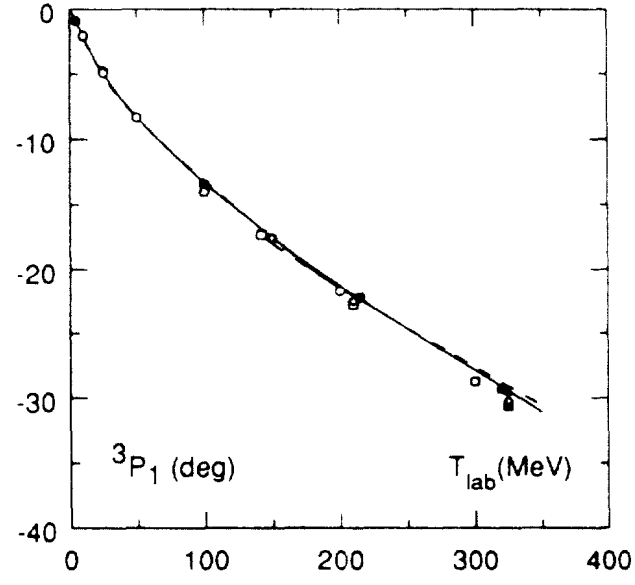
+2

-1


$^1S_0$ (deg)
T_{lab}(MeV)
80
60
40
20
0
-20
0
100
200
300
400


$^3P_0$ (deg)
T_{lab}(MeV)
20
10
0
-10
-20
0
100
200
300
400


$^1D_2$ (deg)
T_{lab}(MeV)
12
10
8
6
4
2
0
0
100
200
300
400

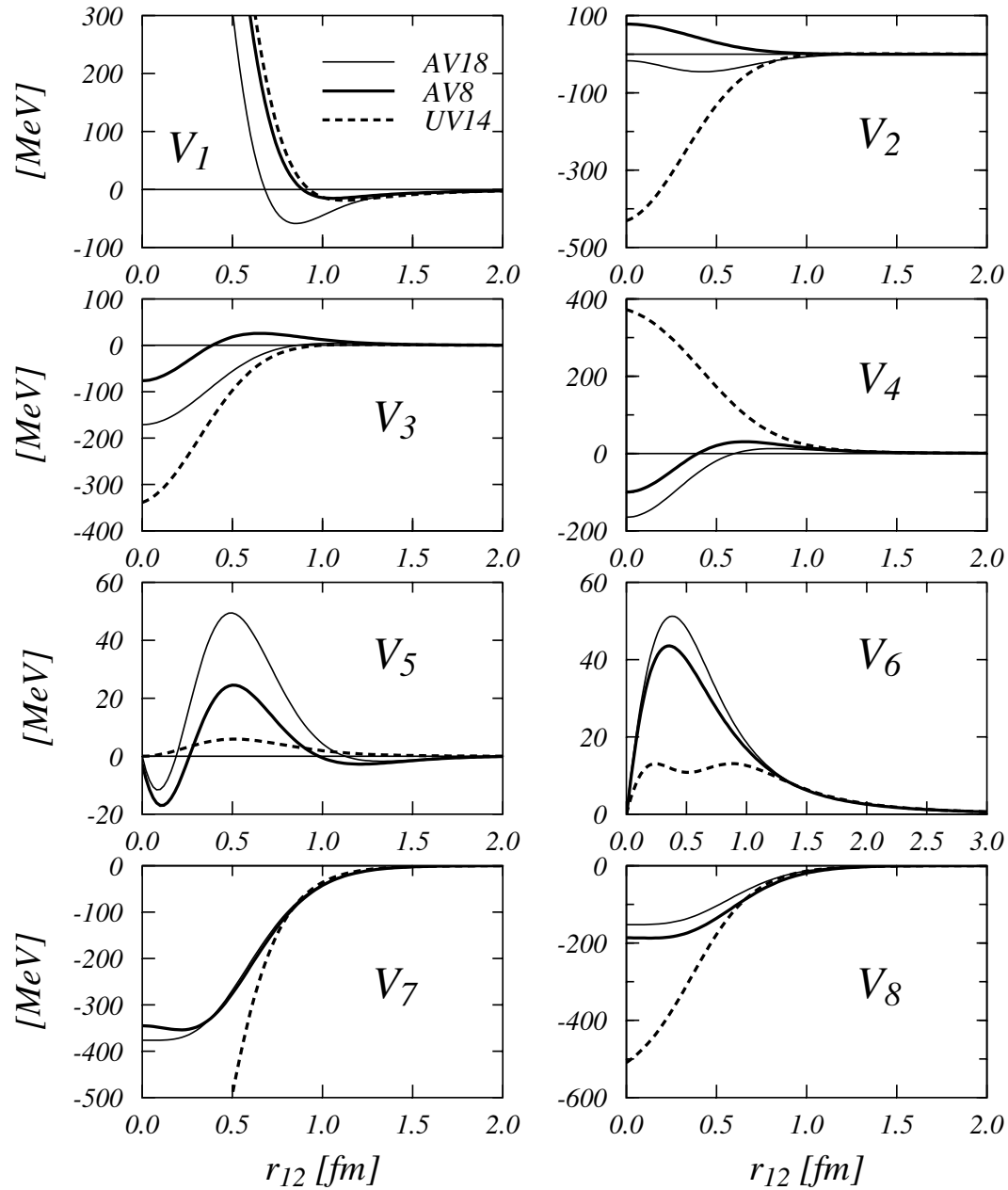

$^3P_1$ (deg)
T_{lab}(MeV)
0
-10
-20
-30
-40
0
100
200
300
400

L'interazione

$$V(i,j) = \sum_{p=1,18} v_p(r_{ij}) O_{ij}^p$$

$$\begin{aligned} O_{ij}^{p=1,14} &= \left[1, \boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j, S_{ij}, (\mathbf{L}\cdot\mathbf{S}), \mathbf{L}^2, \mathbf{L}^2(\boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j), (\mathbf{L}\cdot\mathbf{S})^2\right] \\ &\otimes \left[1, \boldsymbol{\tau}_i \cdot \boldsymbol{\tau}_j\right] \end{aligned}$$

$$O_{ij}^{p=15,18} = [1, \boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j, S_{ij},] \otimes [T_{ij}, \tau_{zi} + \tau_{zj}]$$


AV18
AV8
UV14
V1
V2
V3
V4
V5
V6
V7
V8
[MeV]
r12 [fm]

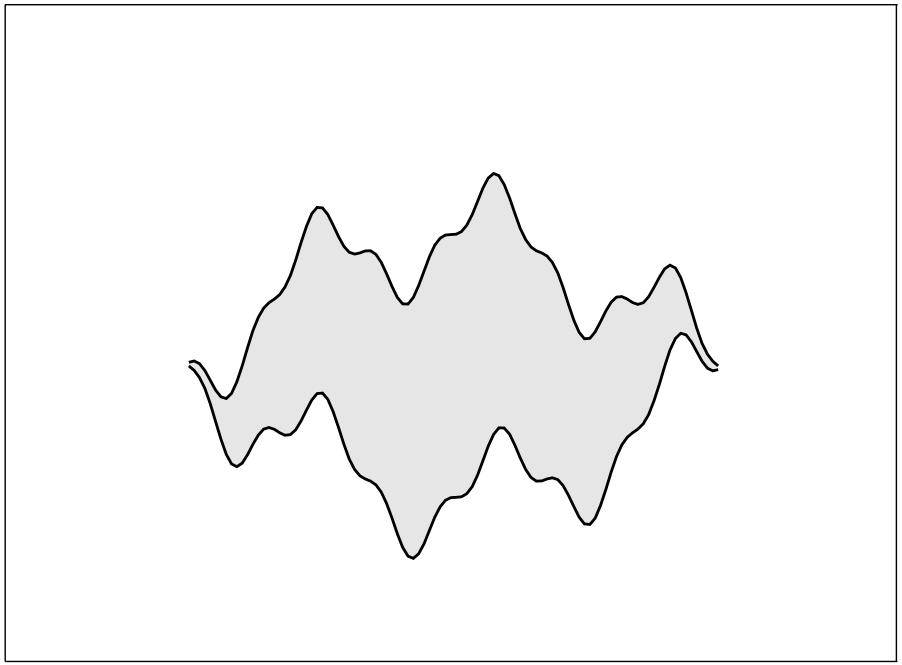
Green's function Monte Carlo

$$\Psi(\tau) = e^{-(H-E_0)\tau}\Psi_T = e^{-(H-E_0)\tau}\sum_N A_N\Psi_N = \sum_N e^{-(E_N-E_0)\tau}A_N\Psi_N$$

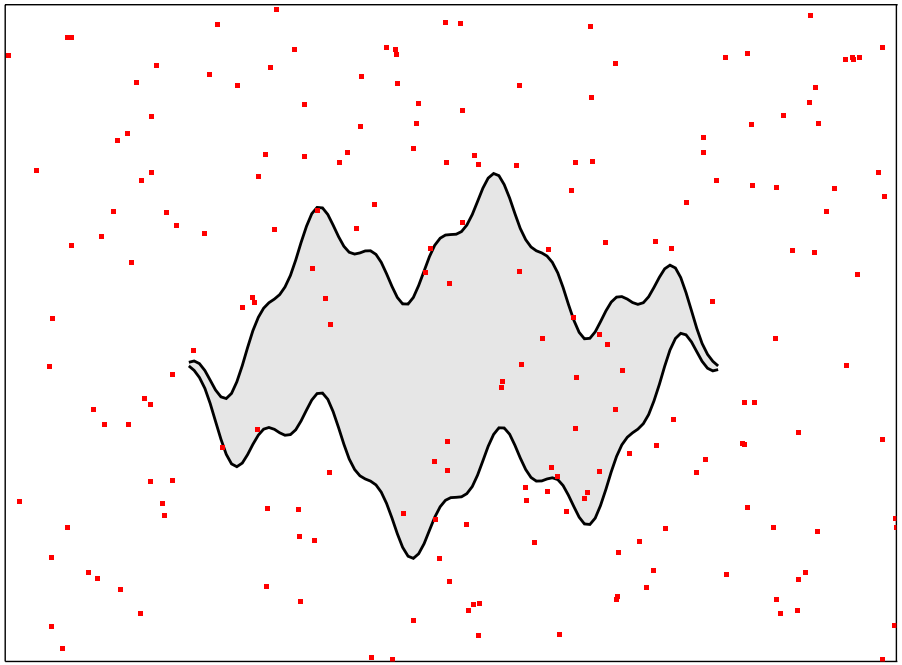
$$\Psi(\tau\rightarrow\infty)\rightarrow A_0\Psi_0$$

$$\frac{<\Psi_T|e^{-(H-E_0)\tau/2}\,H\,e^{-(H-E_0)\tau/2}|\Psi_T>}{<\Psi_T|e^{-(H-E_0)\tau/2}e^{-(H-E_0)\tau/2}|\Psi_T>} \geq E_0$$

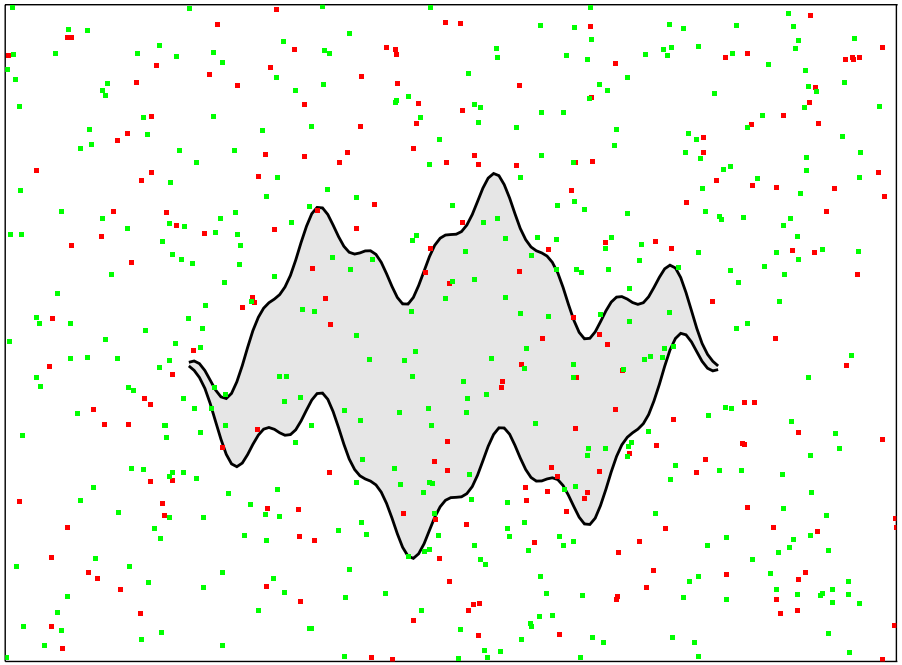
Green's function Monte Carlo



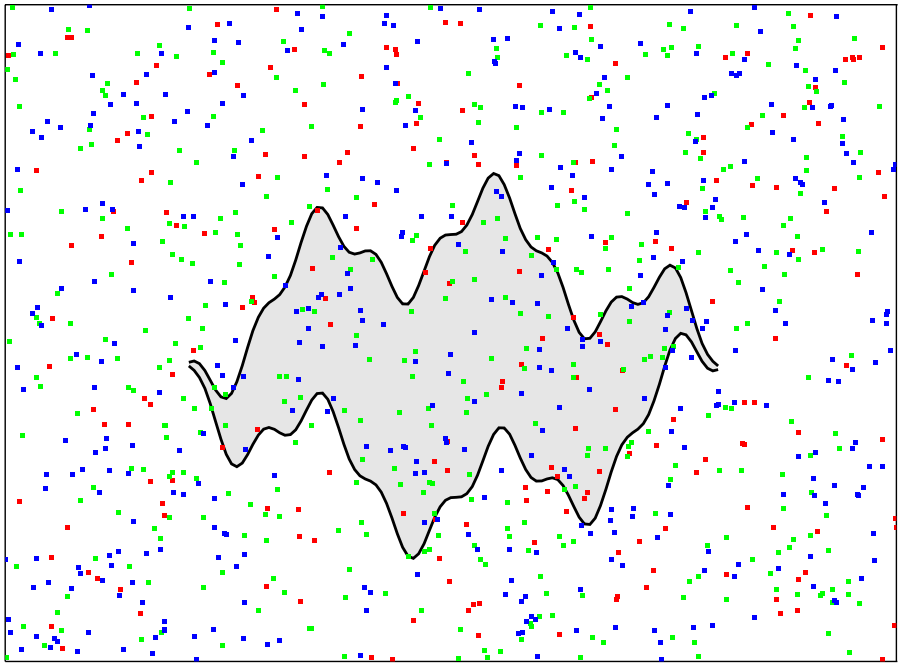
Green's function Monte Carlo



Green's function Monte Carlo



Green's function Monte Carlo

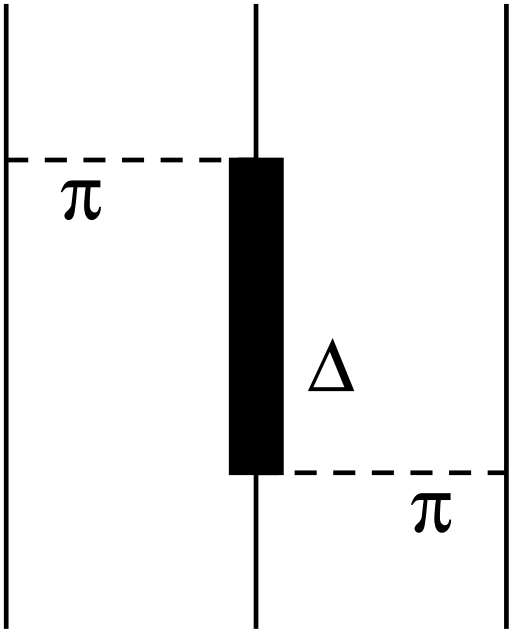


^{3}H Binding energy

Exp 8.48 MeV

2 N potential	2N
CD Bonn	7.953
Nijm II	7.709
Nijm I	7.731
Nijm 93	7.664
Reid 93	7.648
AV14	7.683
AV18	7.576

Forza a 3 corpi



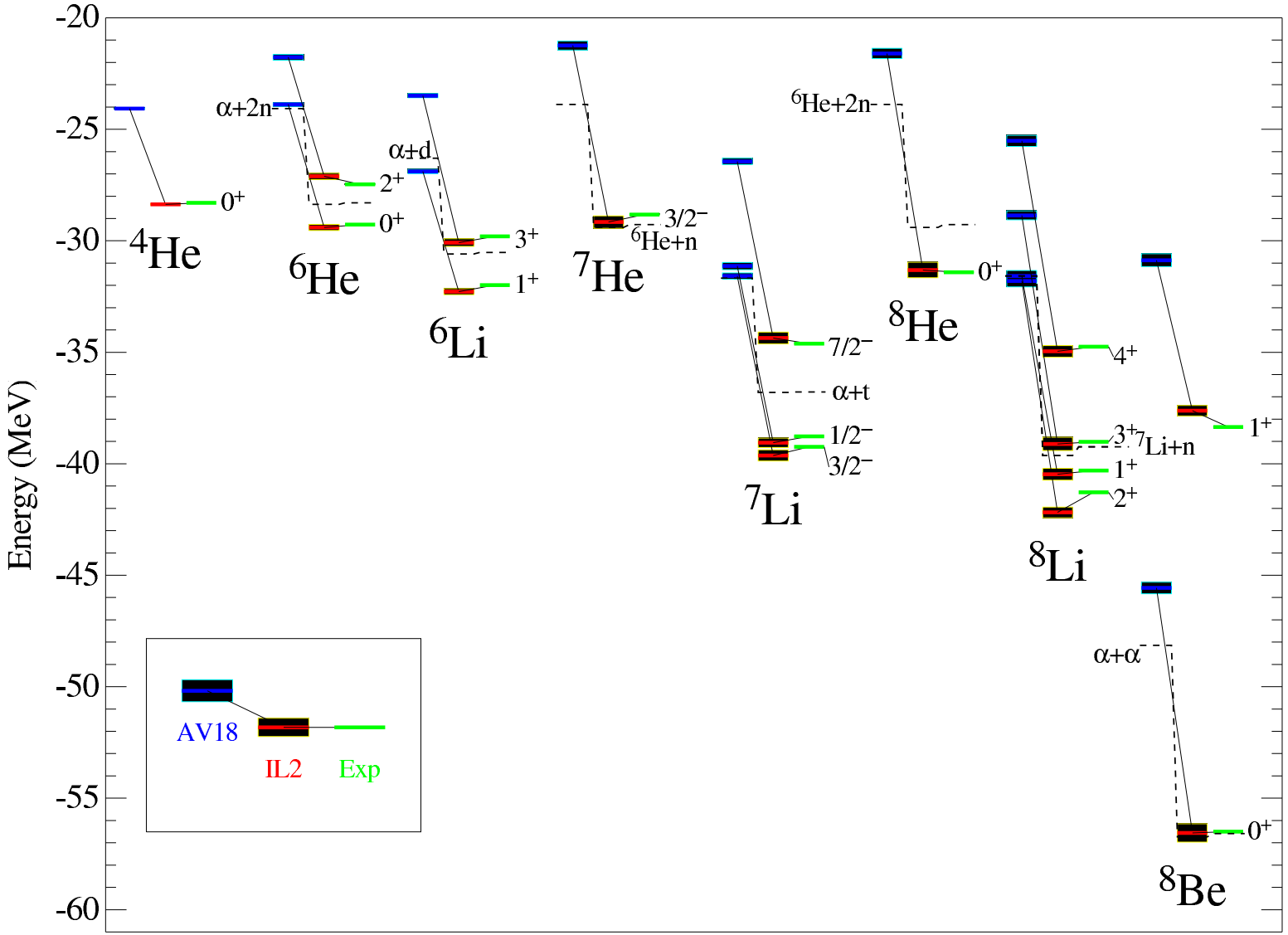
^{3}H Binding energy

Exp 8.48 MeV

2 N potential	2N	2N + 3N
CD Bonn	7.953	8.483
Nijm II	7.709	8.477
Nijm I	7.731	8.480
Nijm 93	7.664	8.480
Reid 93	7.648	8.480
AV14	7.683	8.480
AV18	7.576	8.479

Monte Carlo

S.C. Pieper and R.B. Wiringa, Ann. Rev. Nucl. Part. Sci. 51 (2001) 53.



Introduzione

Numero di configurazioni di spin e isospin per alcuni nuclei.

$$N_{conf} = 2^A \frac{A!}{Z!(A-Z)!}$$

Nucleo	Z	N=A-Z	N_{conf}
^3He	2	1	24
^4He	2	2	96
^6He	2	4	960
^6Li	3	3	1280
^8He	2	6	7168
^{12}C	6	6	3,784,704
^{16}O	8	8	$8.4 \cdot 10^8$
^{40}Ca	20	20	$1.5 \cdot 10^{23}$
^{48}Ca	20	28	$4.7 \cdot 10^{27}$

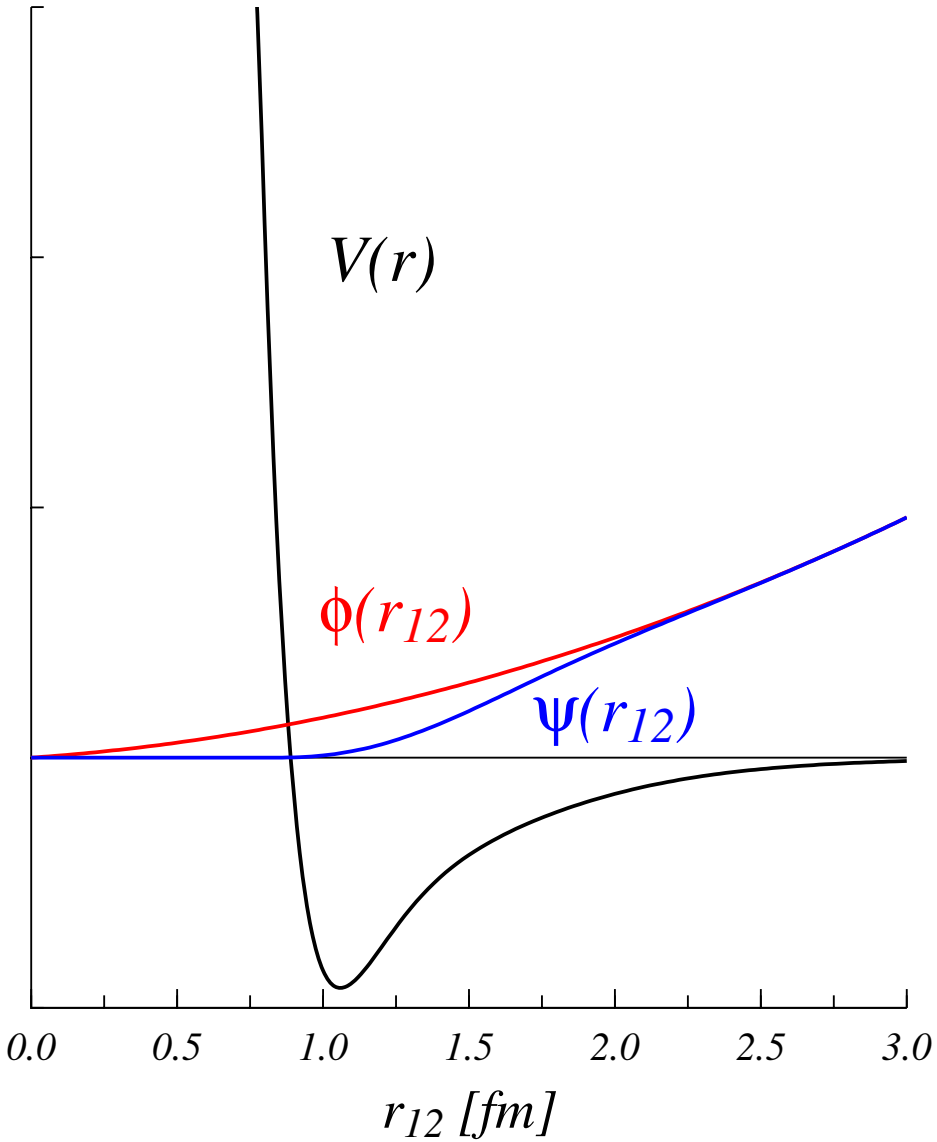
Teoria perturbativa

$$H = H_0 + H_1$$

$$H_0|\Phi_0\rangle = E_0|\Phi_0\rangle$$

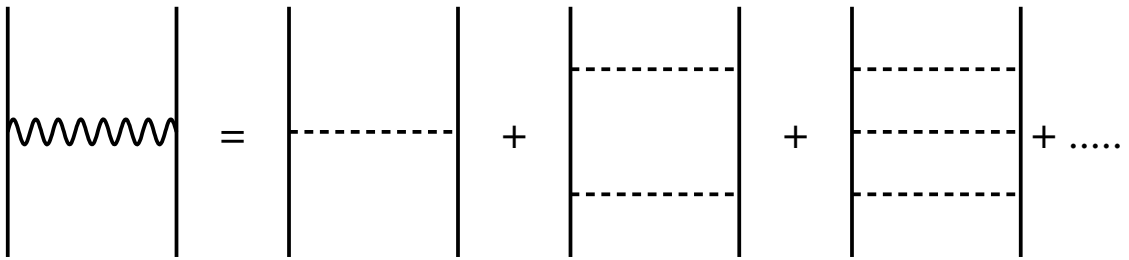
$$H_0|\Phi_0\rangle = \sum_i h_i \prod_{k=1,A} |\phi_k\rangle = \sum_i \epsilon_i \prod_{k=1,A} |\phi_k\rangle$$

$$\begin{aligned} E &= \langle\Phi_0|H_0|\Phi_0\rangle + \langle\Phi_0|H_1 \sum_{n=0}^{\infty} \left(\frac{1}{E_0 - H_0} H_1\right)^n |\Phi_0\rangle_c \\ &= E_0 + \langle\Phi_0|H_1|\Phi_0\rangle + \langle\Phi_0|H_1 \frac{1}{E_0 - H_0} H_1|\Phi_0\rangle_c + \cdots \end{aligned}$$


V(r)
ϕ(r12)
ψ(r12)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
r12 [fm]

Matrice G

$$\begin{aligned}\langle\Phi_0|G(\omega)|\Phi_0\rangle &= \langle\Phi_0|H_1|\Phi_0\rangle \\ &+ \sum_{p,q>F} \frac{\langle\Phi_0|H_1|\Phi_{pq}\rangle\langle\Phi_{pq}|G(\omega)|\Phi_0\rangle}{\omega-\epsilon_p-\epsilon_q}\end{aligned}$$



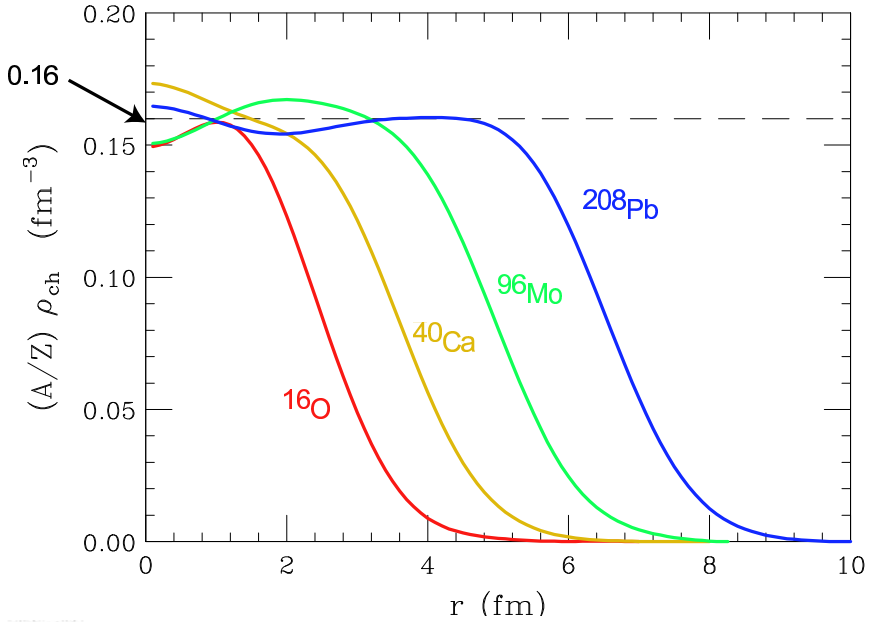
G

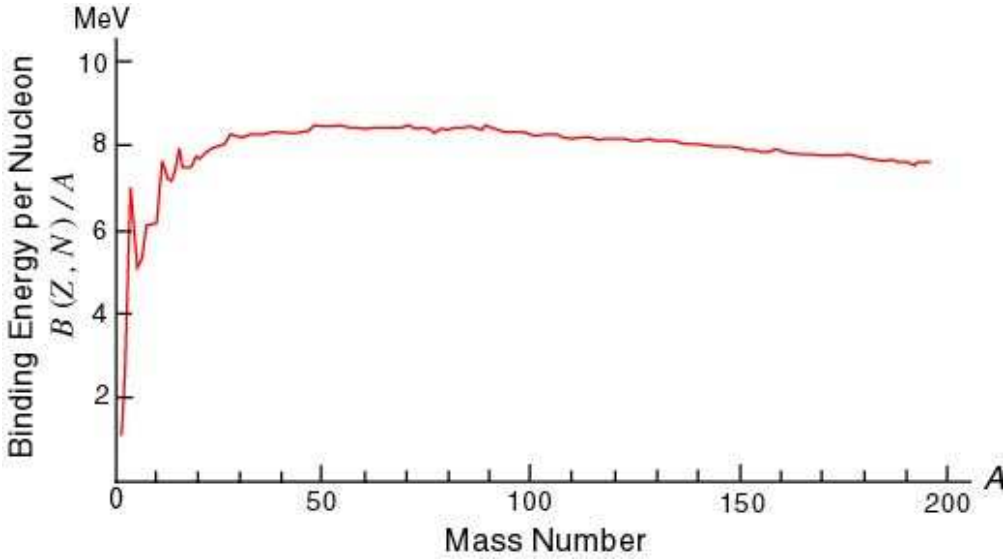
Base correlata

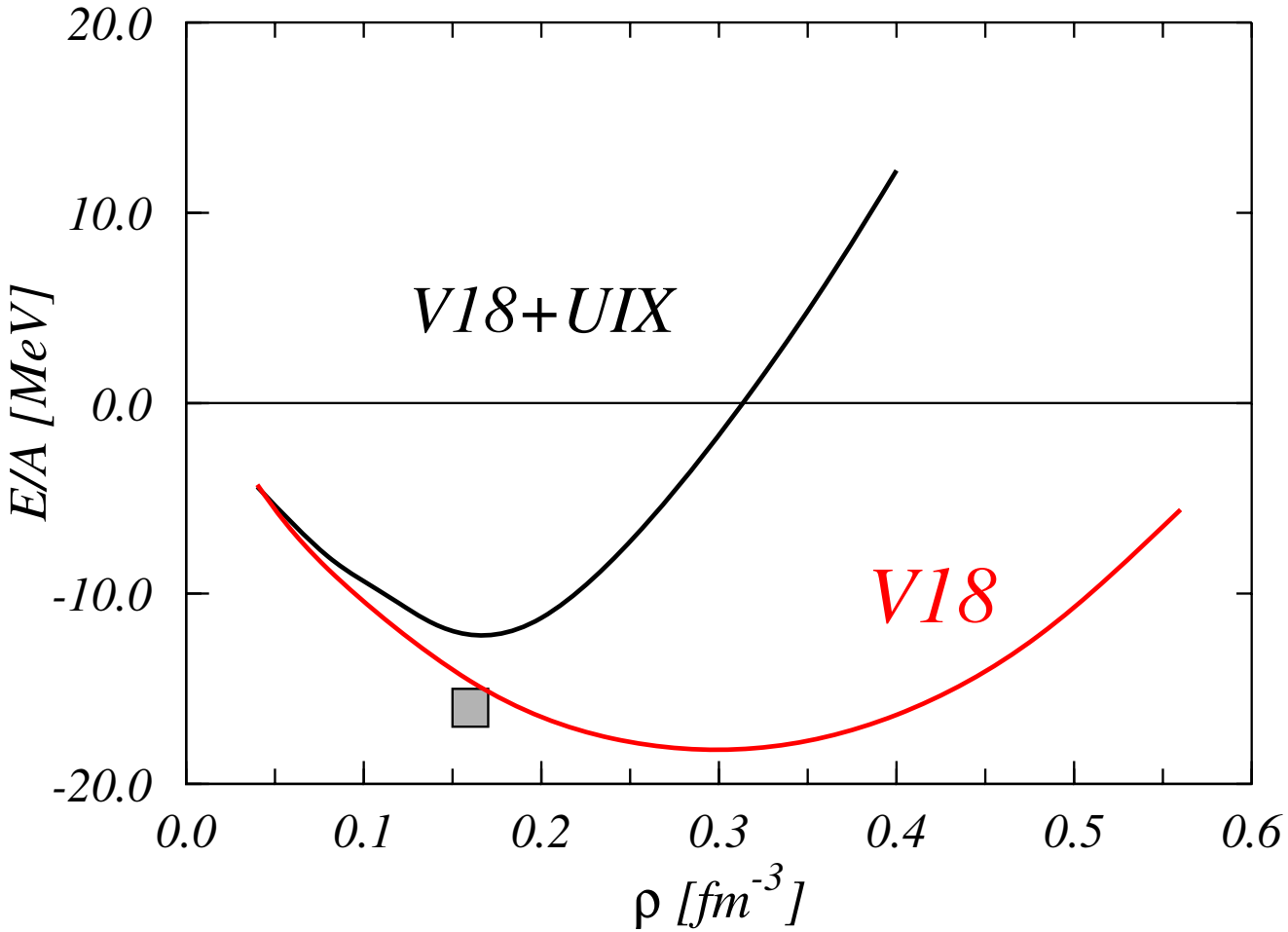
Principio Variazionale

$$\Psi(1,2,...,A) = F(1,2,...,A)\Phi(1,2,....,A)$$

$$\delta E[\Psi] = \delta\left[\frac{<\Psi|H|\Psi>}{<\Psi|\Psi>}\right] = \delta\left[\frac{<\Phi|F^{\dagger}HF|\Phi>}{<\Psi|\Psi>}\right] = 0$$


0.20
0.16
0.15
0.10
0.05
0.00
(A/Z) ρ_{ch} (fm^{-3})
^{208}Pb
^{96}Mo
^{40}Ca
^{16}O
0
2
4
6
8
10
r (fm)


MeV
10
8
6
4
2
Binding Energy per Nucleon
$B(Z,N)/A$
0
50
100
150
200
A
Mass Number


20.0
10.0
0.0
-10.0
-20.0
E/A [MeV]
V18+UIX
V18
0.0
0.1
0.2
0.3
0.4
0.5
0.6
ρ [fm^-3]

Risultati

		^{12}C	^{16}O	^{40}Ca	^{48}Ca	^{208}Pb
$v_8' + UIX$	T	27.13	32.33	41.06	39.64	39.56
	V^6_{2-body}	-29.13	-38.15	-48.97	-46.60	-48.43
	V_{LS}	-0.51	-0.70	-0.85	-0.79	-0.80
	V_{Coul}	0.67	0.86	1.96	1.57	3.97
	$T + V(2)$	-1.84	-5.66	-6.83	-6.24	-5.80
	V_{3-body}	0.66	0.86	1.76	1.61	1.91
	E	-1.17	-4.80	-5.05	-4.62	-3.78
$v_{14} + UVII$	T	24.63	29.25	37.70	36.47	36.48
	V^6_{2-body}	-27.08	-35.84	-47.16	-44.86	-46.87
	V_{LS}	-0.06	-0.10	-0.10	-0.09	-0.08
	V_{Coul}	0.68	0.88	2.02	1.59	4.03
	$T + V(2)$	-1.83	-5.81	-7.54	-6.89	-6.44
	V_{3-body}	0.54	0.69	1.28	1.15	1.41
	E	-1.29	-5.12	-6.26	-5.74	-5.03
	E_{exp}	-7.68	-7.97	-8.55	-8.66	-7.86

Campo medio: Hartree Fock

$$\begin{aligned}\delta E[\Psi] &= \delta\left[\frac{<\Psi|H|\Psi>}{<\Psi|\Psi>}\right] = \delta\left[\frac{<\Phi|F^{\dagger}HF|\Phi>}{<\Psi|\Psi>}\right] \\ &\simeq \delta\left[\frac{<\Phi|H_{eff}|\Phi>}{<\Phi|\Phi>}\right] = 0\end{aligned}$$

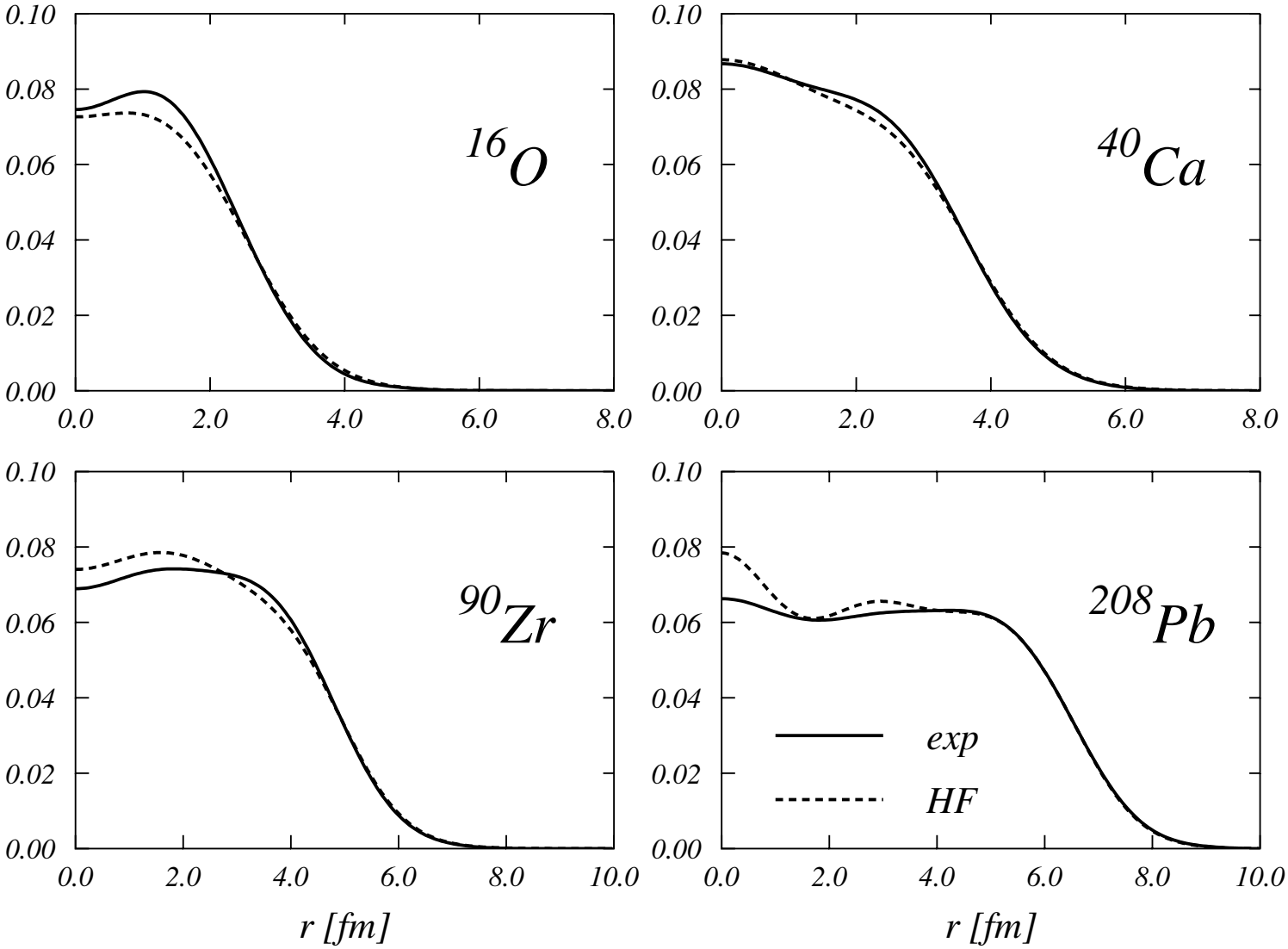
$H_{eff} = \sum_i h_i$ fenomenologica

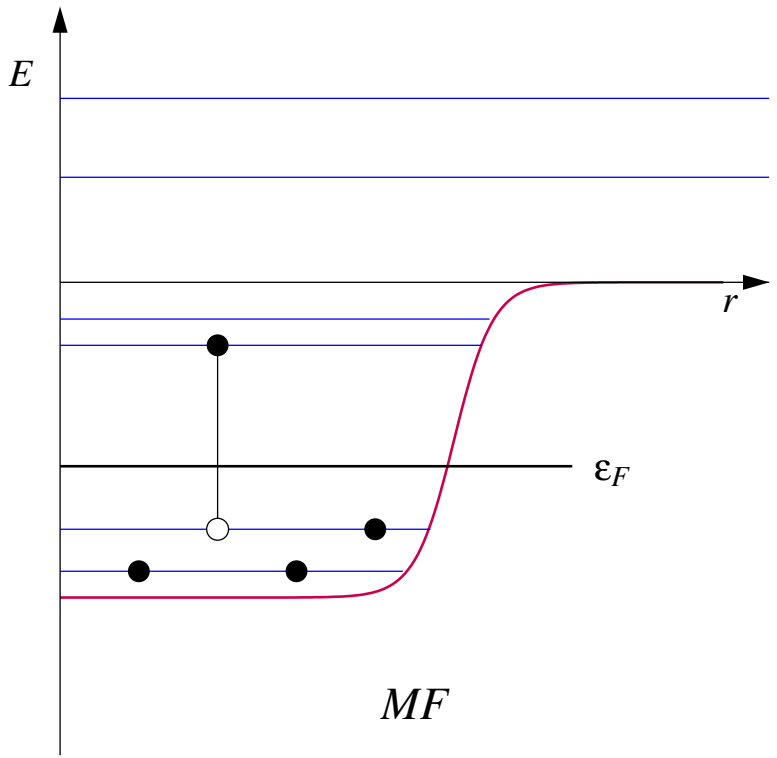
$$\Phi(x_1 \ldots x_A) = \frac{1}{\sqrt{A!}} \begin{vmatrix} \phi_{\nu_1}(x_1) & \ldots & \phi_{\nu_A}(x_1) \\ \vdots & & \vdots \\ \phi_{\nu_1}(x_A) & \ldots & \phi_{\nu_A}(x_A) \end{vmatrix}$$

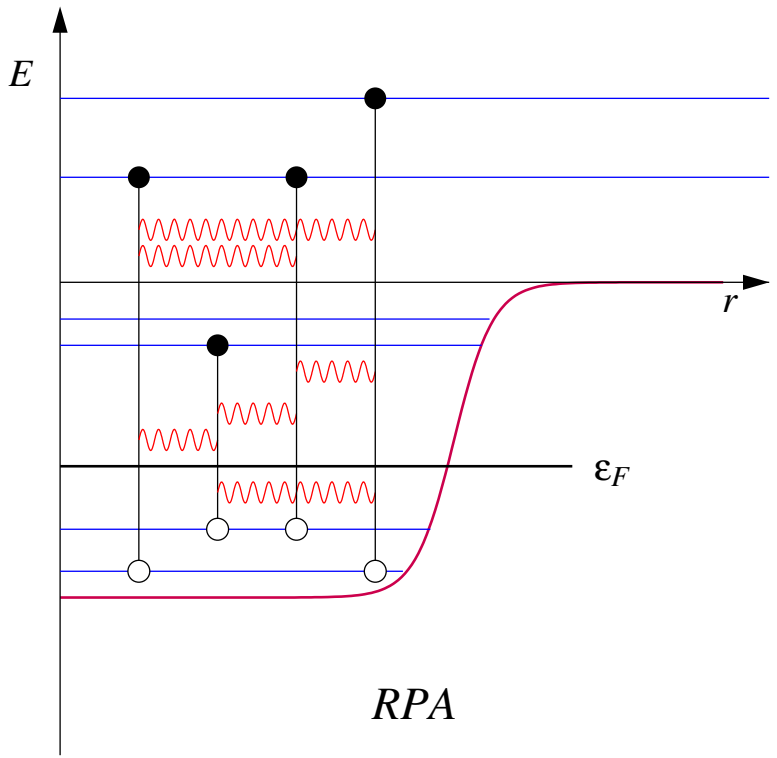
$$
\begin{aligned}
H &= \sum_i T_i + \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} \\
&= \sum_i T_i + \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} + \sum_i U_i - \sum_i U_i \\
&= \sum_i (T_i + U_i) + \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} - \sum_i U_i \\
&= \sum_i h_i + \sum_{i<j} V_{ij} + \sum_{i<j<k} V_{ijk} - \sum_i U_i \\
&= H_{eff} + V_{res}
\end{aligned}
$$

$$\Delta = 100 \frac{|B_{HF} - B_{exp}|}{B_{exp}}$$

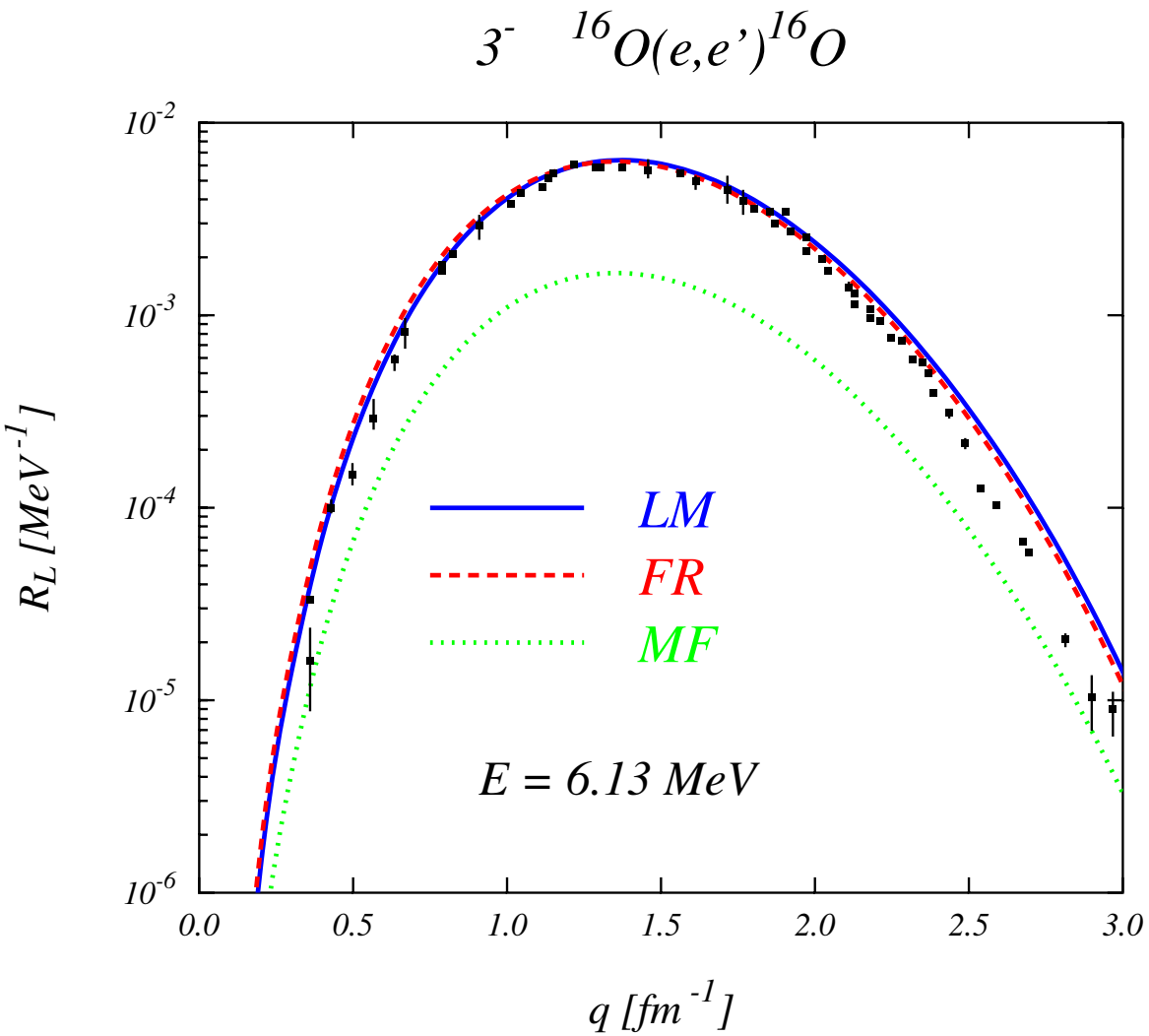
	B_{HF} [MeV]	B_{exp} [MeV]	Δ
^{16}O	8.275	7.975	3.76
^{40}Ca	8.679	8.552	1.48
^{48}Ca	8.742	8.667	0.86
^{90}Zr	8.707	8.710	0.034
^{132}Sn	8.307	8.355	0.57
^{208}Pb	7.747	7.867	1.52


0.10
0.08
0.06
0.04
0.02
0.00
0.0
2.0
4.0
6.0
8.0
10.0
^{16}O
^{40}Ca
^{90}Zr
^{208}Pb
exp
HF
r [fm]


E
r
ε_F
MF


E
r
ε_F
RPA

Diffusione di elettroni



Fotoassorbimento