

Marciana Marina (Elba), June, 21- 25, 2010

Effective nuclear many-body theories

V. De Donno and G. Co'

University of Salento and INFN Lecce (Italy)

M. Anguiano and A. M. Lallena

University of Granada (Spain)

Effective theory

$$H|\Psi\rangle = E|\Psi\rangle \quad H^{\text{eff}}|\Psi^{\text{eff}}\rangle = E|\Psi^{\text{eff}}\rangle$$

$$H = H_0 + H_1 \quad H_0 P|\Psi\rangle = \omega P|\Psi\rangle \quad P^2 = P \quad Q = I - P$$

$$\left[H_0 + P \left(H_1 + H_1 Q \frac{1}{E - H_0 - Q H_1 Q} Q H_1 \right) P \right] P|\Psi\rangle = E P|\Psi\rangle$$

$$\left[H_0 + V^{\text{eff}}(E) \right] P|\Psi\rangle = E P|\Psi\rangle$$

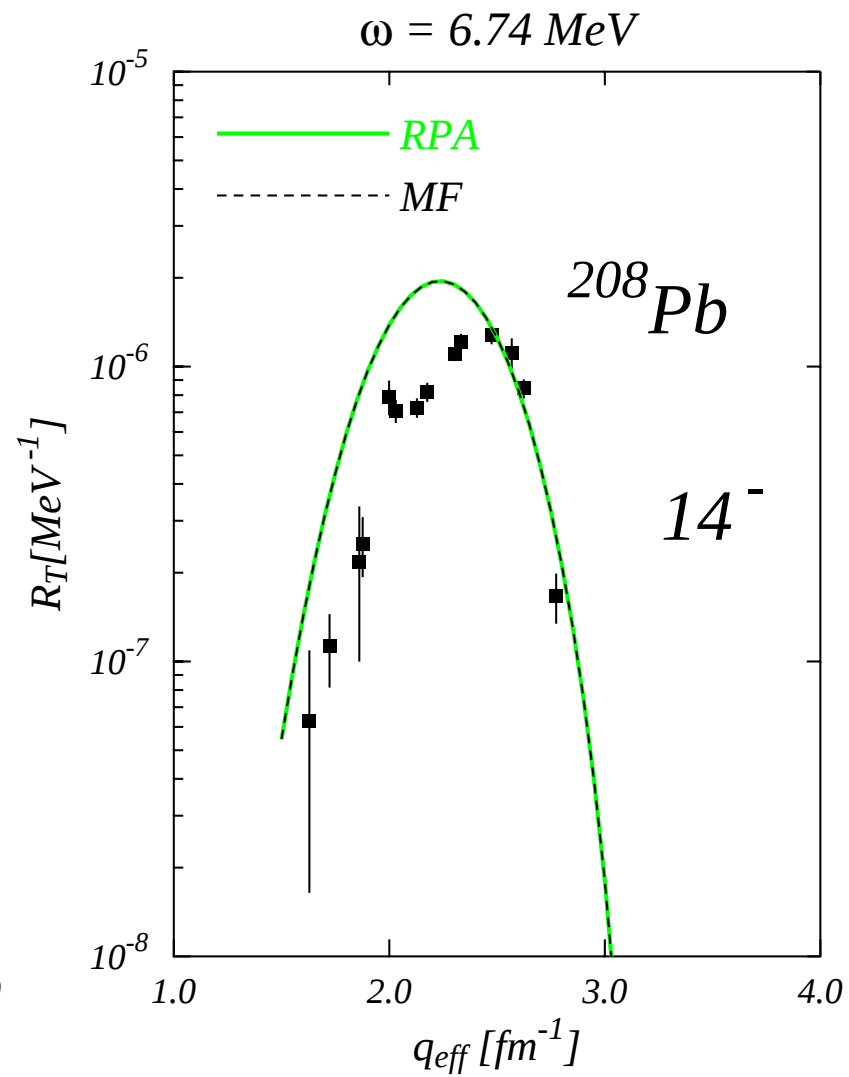
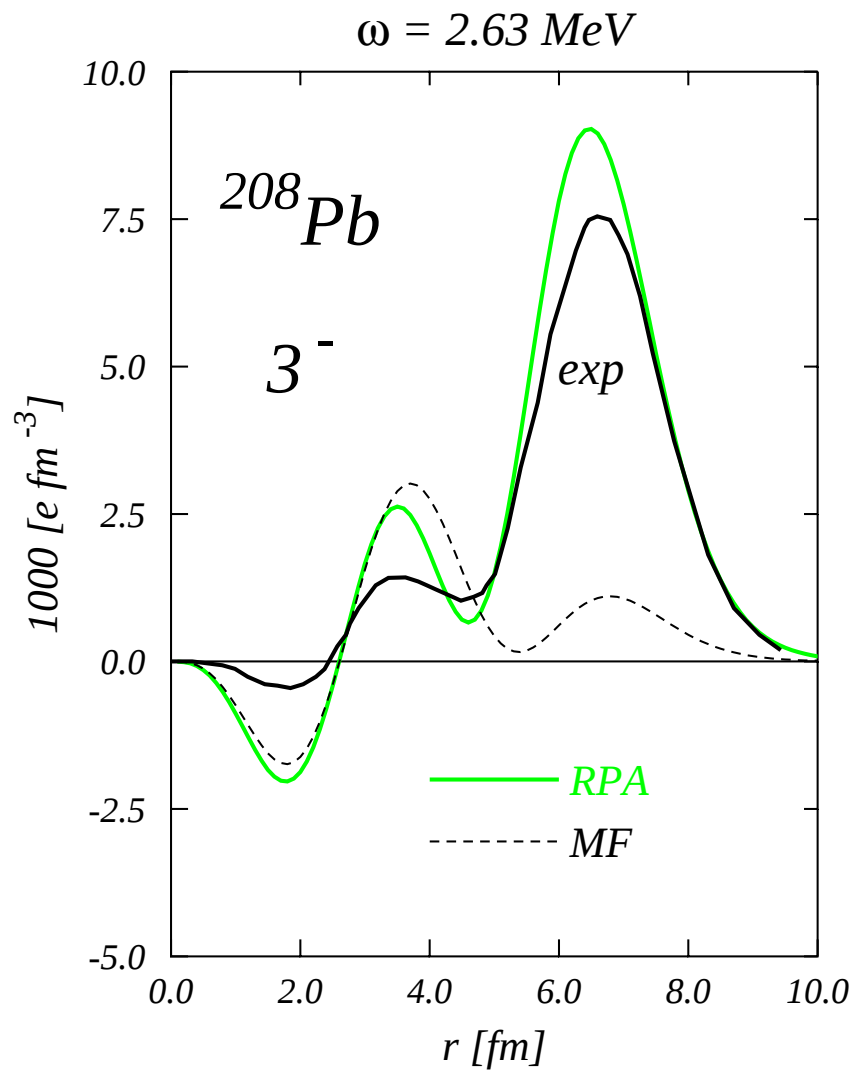
Effective hamiltonian depends on the choice of H_0

Effective hamiltonian depends on the energy E

Phenomenological Random Phase Approximation (RPA) calculations

- Single particle wavefunctions from Woods-Saxon potentials.
- Experimental single particle energies (when available)
- Effective nucleon-nucleon interaction chosen to reproduce some empirical quantity.

The input changes for each nucleus.



3^- data: D. Goutte et al., Phys. Rev. Lett. 45 (1980) 1618

14^- data: J. Linchtenstadt et al., Phys. Rev. C 20 (1979) 497

Self-consistent RPA calculations

Single particle bases taken from Hartree-Fock (HF) calculations

The same interaction is used in HF and RPA

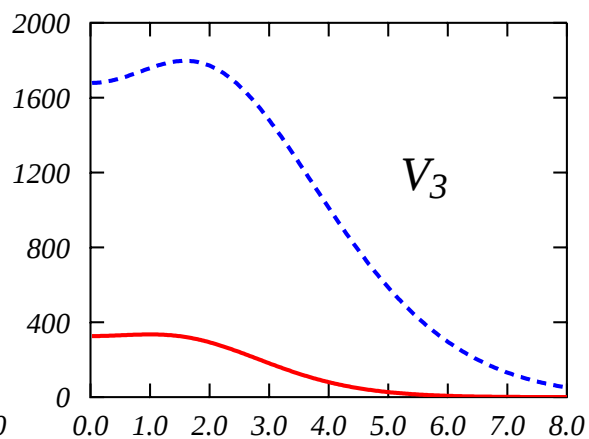
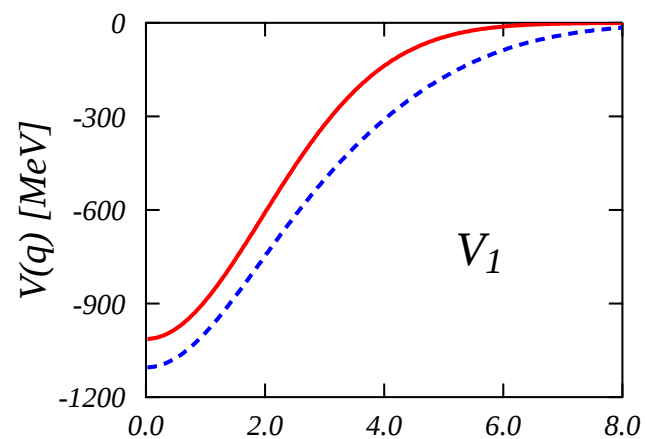
A unique interaction for all the nuclei

Our choice

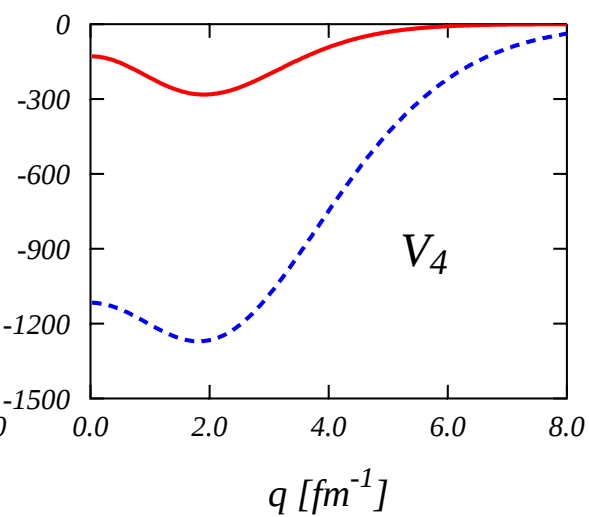
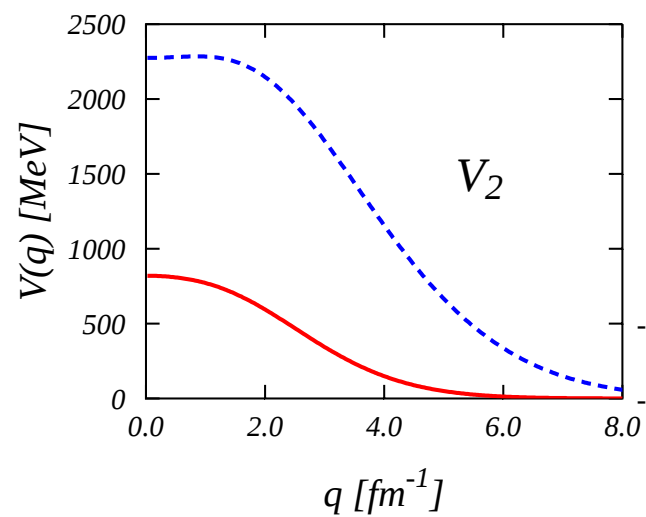
- Gogny-like interactions
- finite range
- zero-range Spin-Orbit term
- zero-range Density dependent term
- 14 parameters chosen with a fit of about 2000 nuclear binding energies and 700 charge radii.

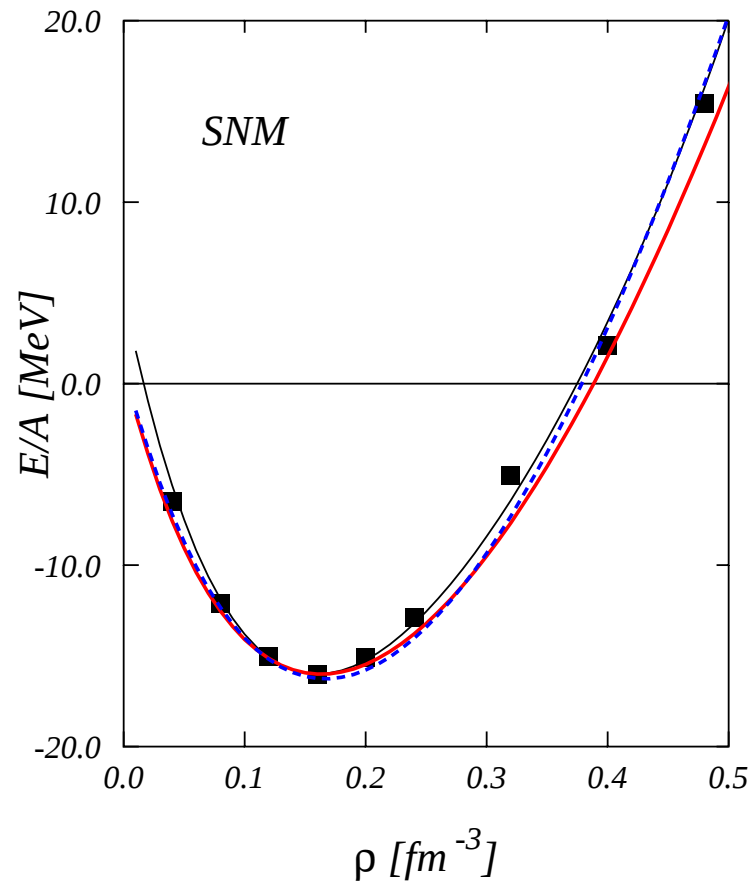
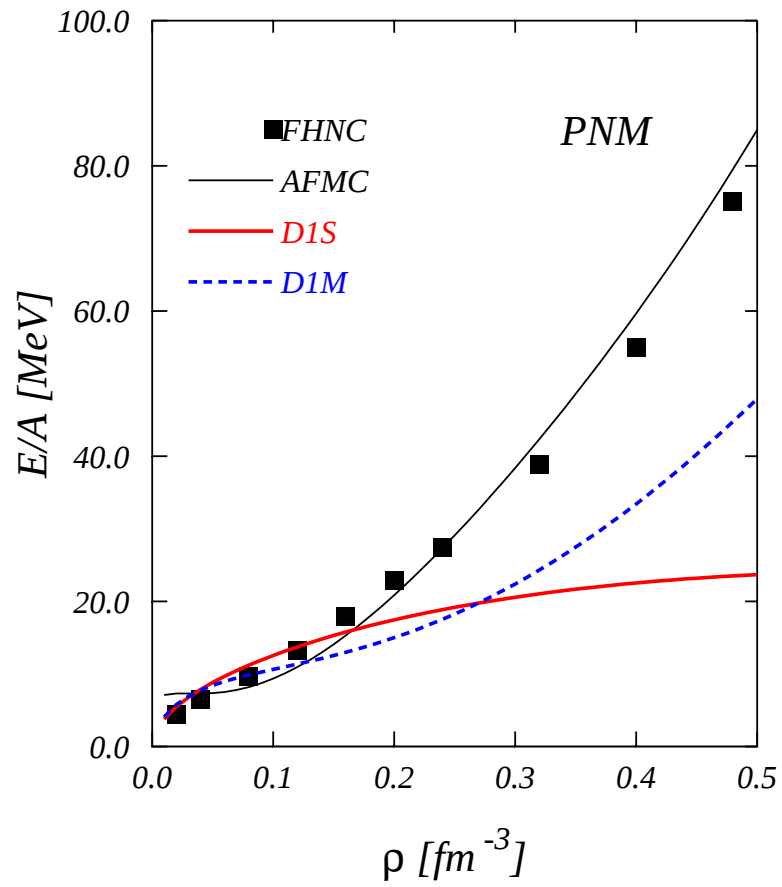
Two parameterizations

- **D1S**: J. F. Berger et al., Comp. Phys. Comm. 63 (1991) 365
- **D1M**: S. Goriely et al., Phys. Rev. Lett. 102 (2009) 252501



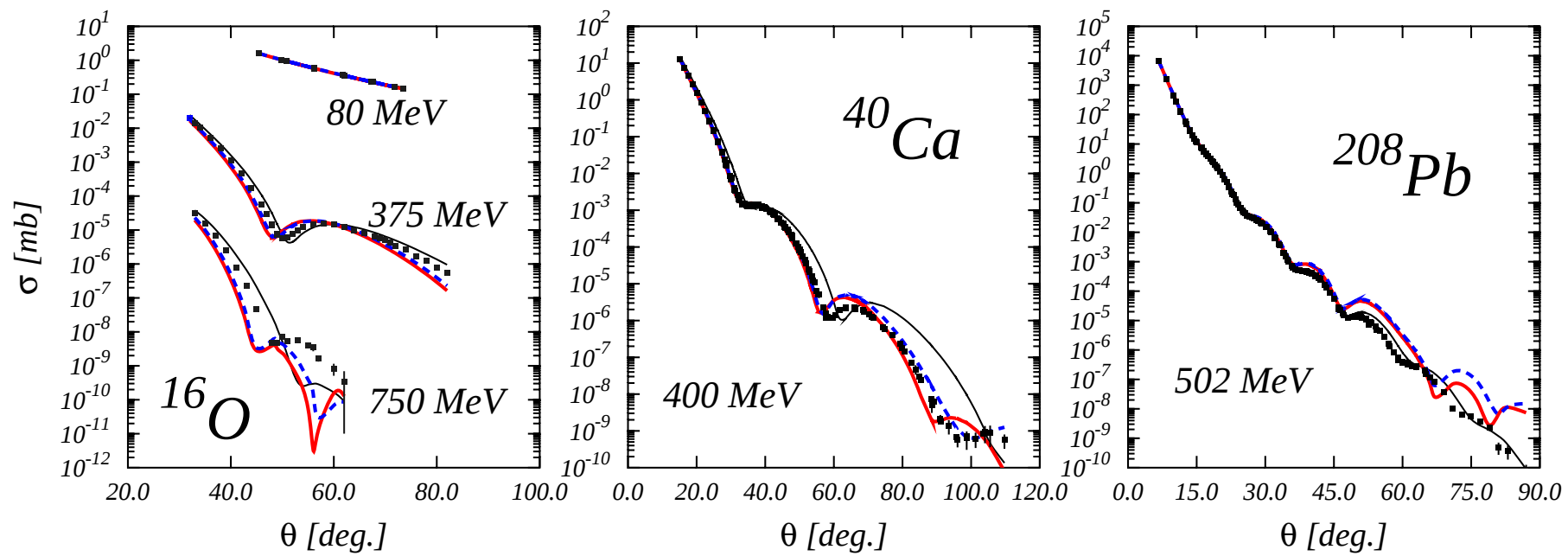
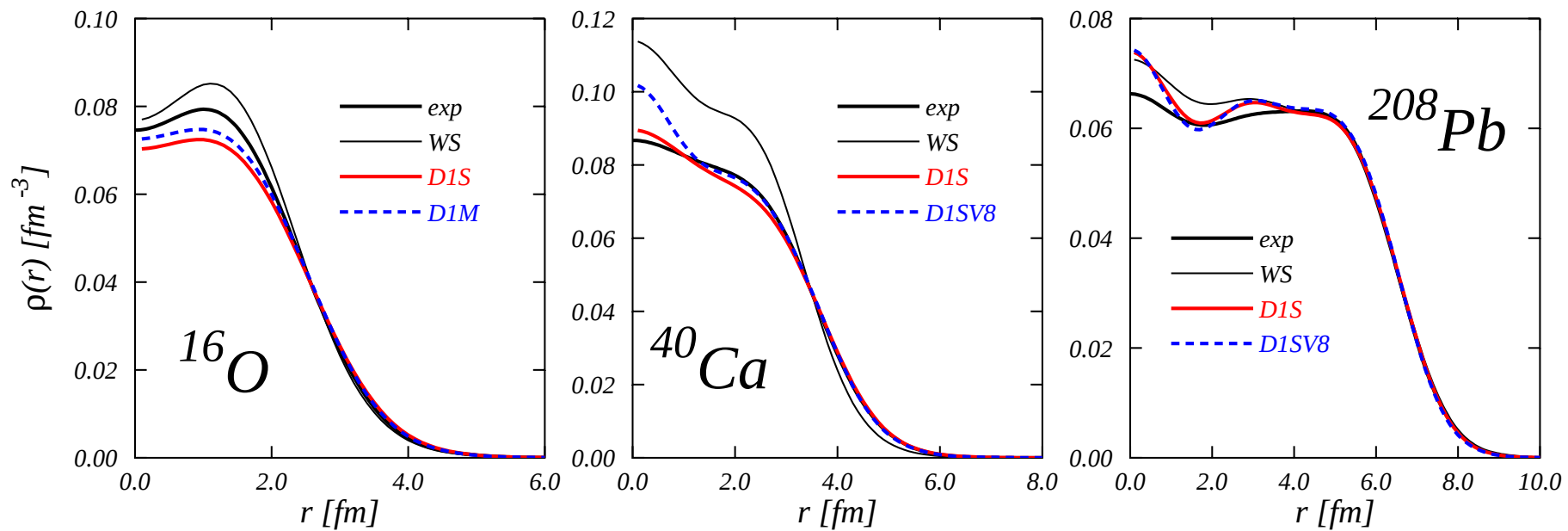
— $D1S$
- - - $D1M$

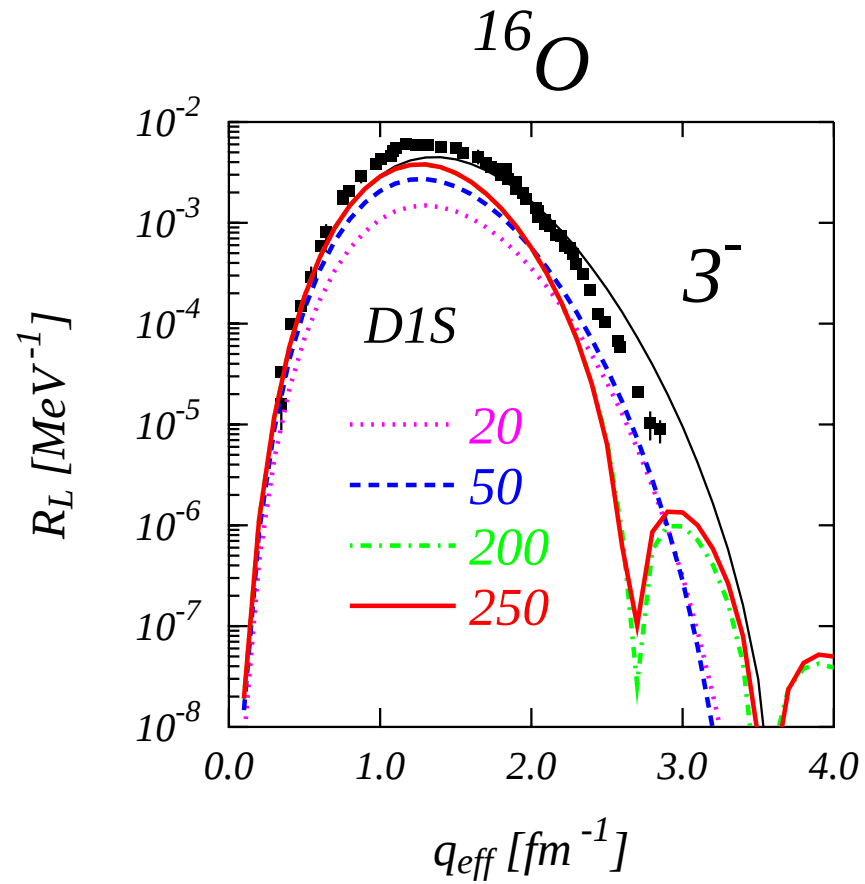




FHNC: A. Akmal et al., Phys Rev C 58 (1998) 1804

AFMC: S. Gandolfi et al., Mon. Not. Roy. Astron. Soc. 404 (2010) L35





$\epsilon_{ph}^{\text{max}} [\text{MeV}]$	$\omega [\text{MeV}]$
20.0	9.11
50.0	8.55
200.0	7.87
250.0	7.85
exp	6.13

Data: T. N. Buti et al., Phys. Rev. C 33 (1986) 755

Continuum in RPA

(A pedagogical and simplified presentation)

$$(\epsilon_p - \epsilon_h - \omega)X_{ph}(\epsilon_p) + \sum_{p'h'} \int d\epsilon_{p'} v_{ph,p'h'}(\epsilon_p, \epsilon_{p'})X_{ph}(\epsilon'_{p'}) = 0$$

Definition of a new unknown

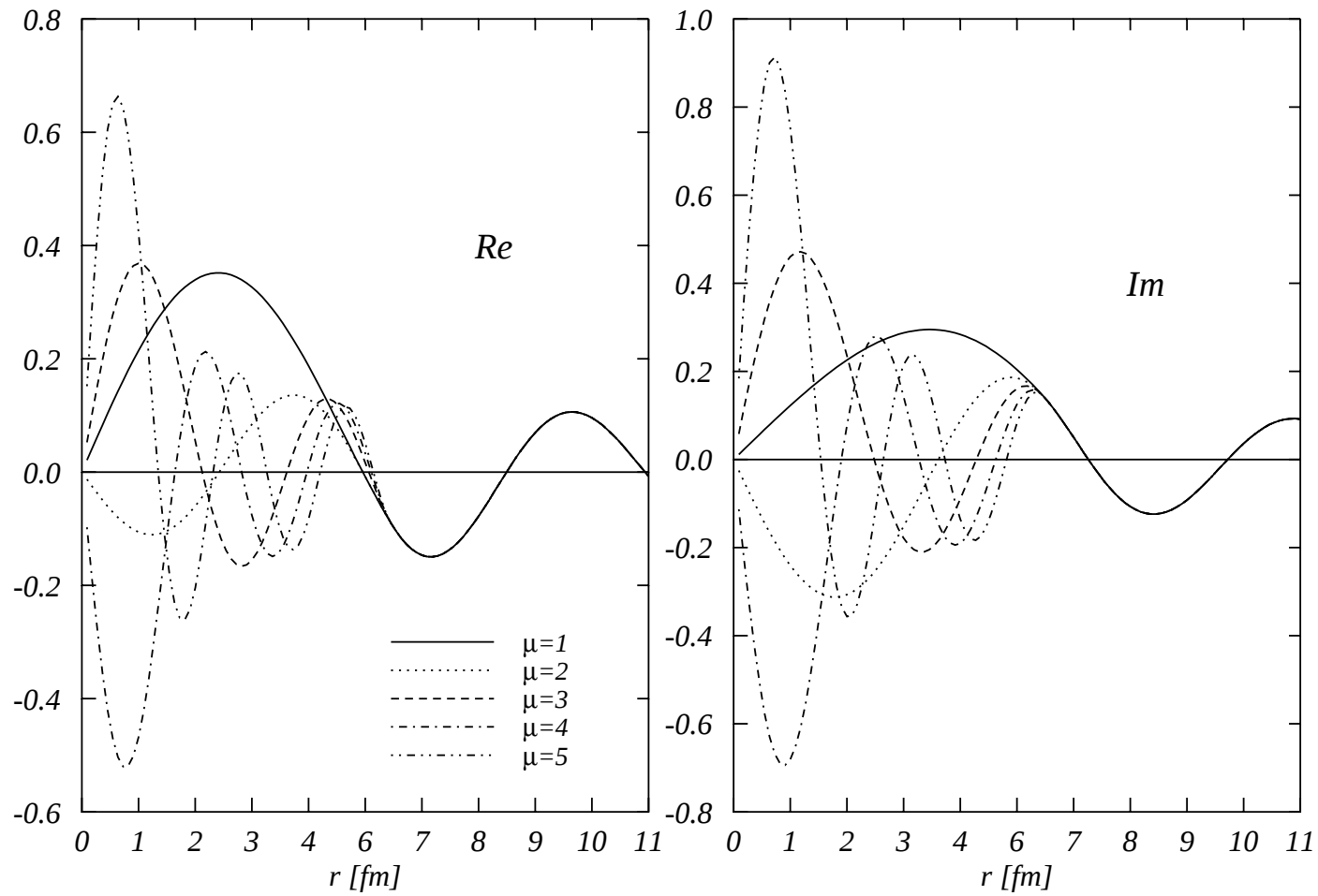
$$f_{ph}(r) = \int d\epsilon_p X_{ph}(\epsilon_p) R_p(r, \epsilon_p)$$

A new equation to be solved

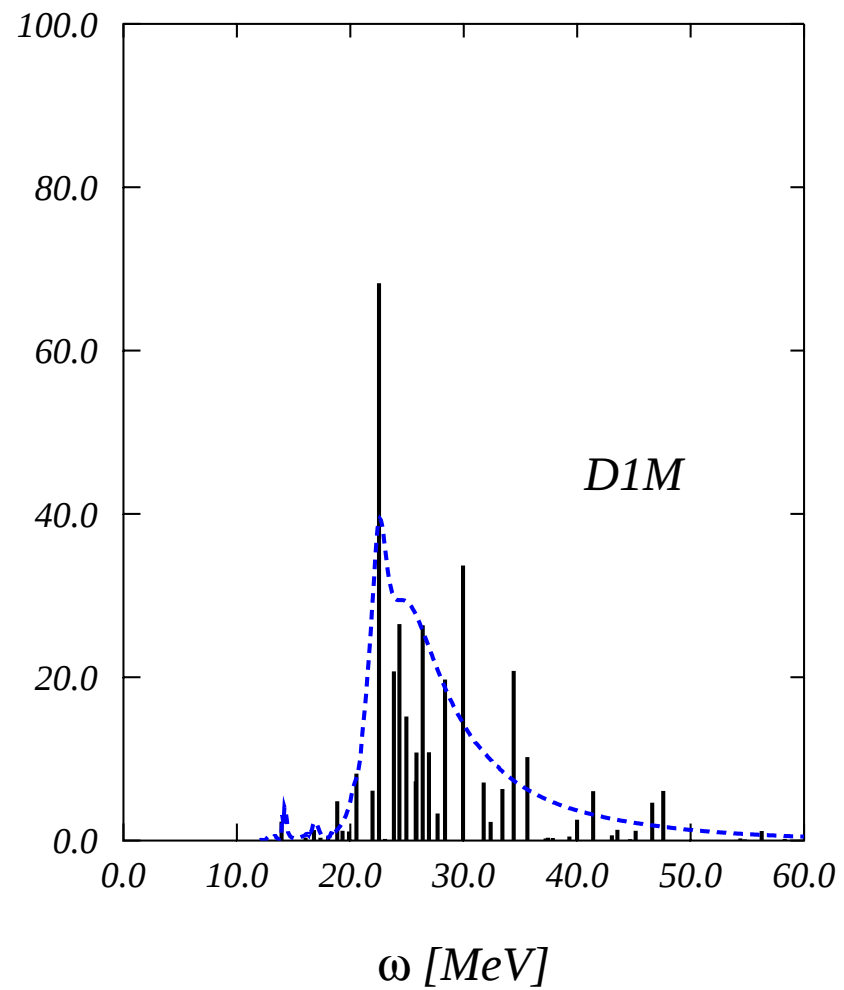
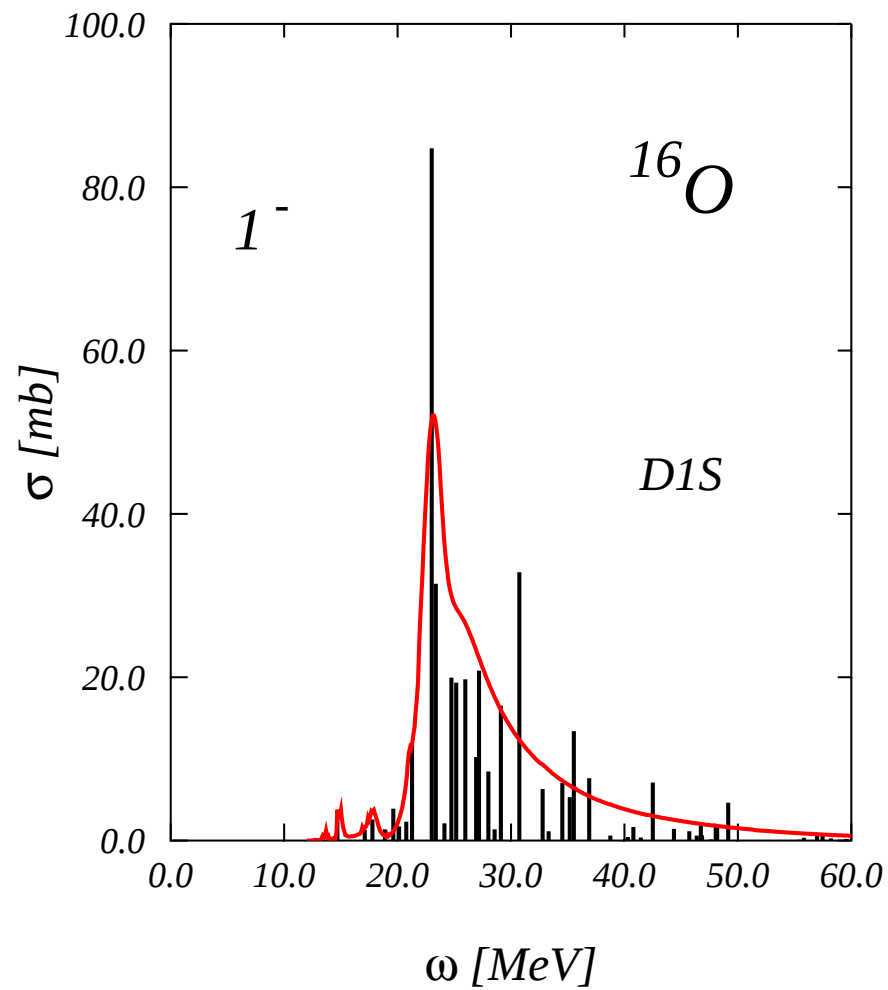
$$0 = -\frac{\hbar^2}{2m} \nabla^2 f_{ph}(r) + U(r) f_{ph}(r) - \int dr' r'^2 W(r, r') f_{ph}(r') - (\epsilon_h + \omega) f_{ph}(r) \\ - \sum_{p'h'} \int dr' r'^2 \left[R_{h'}^*(r') v^{\text{dir}}(r, r') R_h^*(r) f_{p'h'}(r') - R_{h'}^*(r') v^{\text{exc}}(r, r') R_h^*(r') f_{p'h'}(r) \right]$$

Expansion of $f_{ph}(r)$ on a Sturm-Bessel functions basis

Sturm-Bessel functions

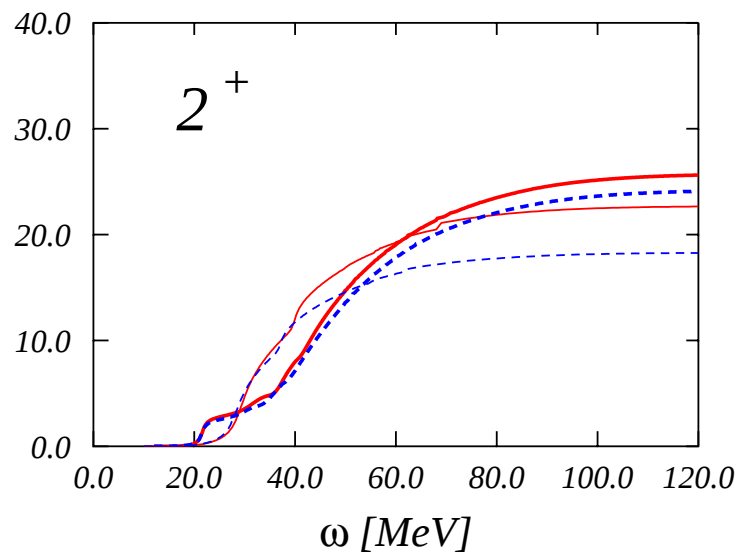
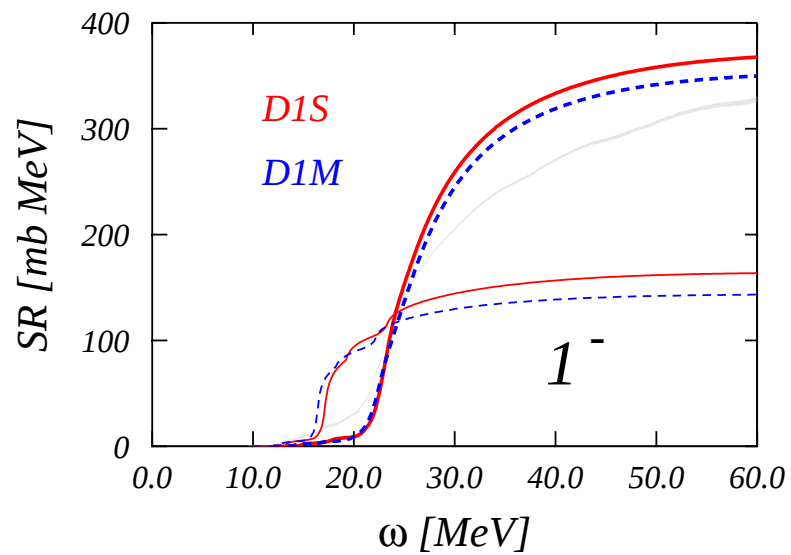
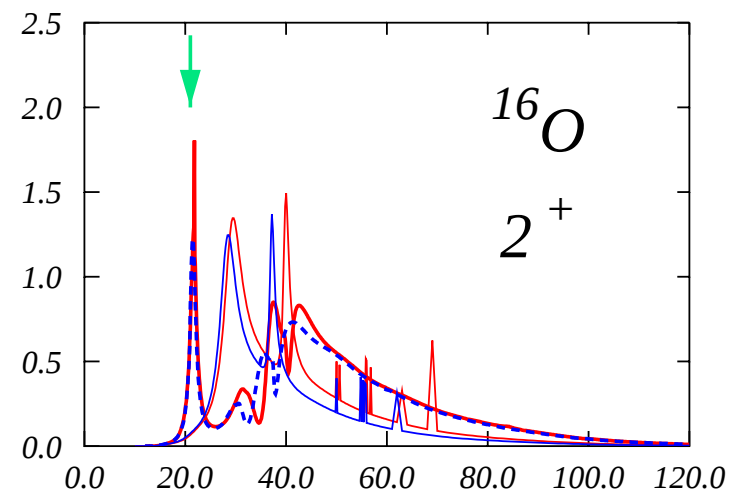
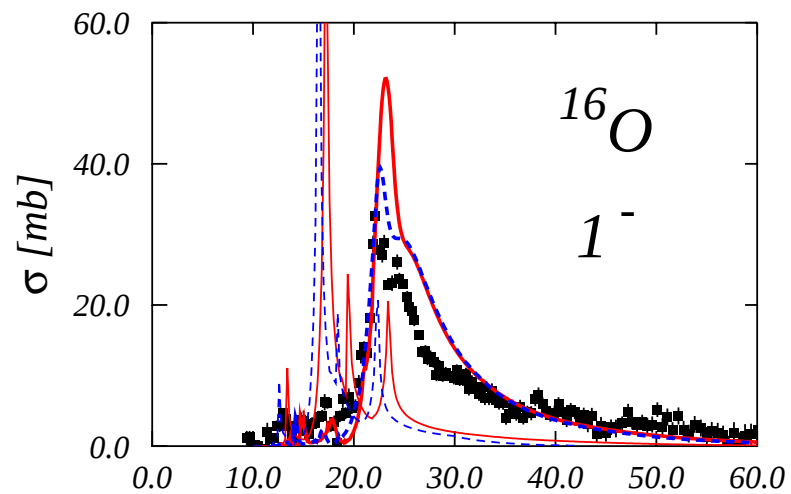


$$\epsilon=30 \text{ MeV}, l=1, j=3/2, {}^{16}\text{O}$$



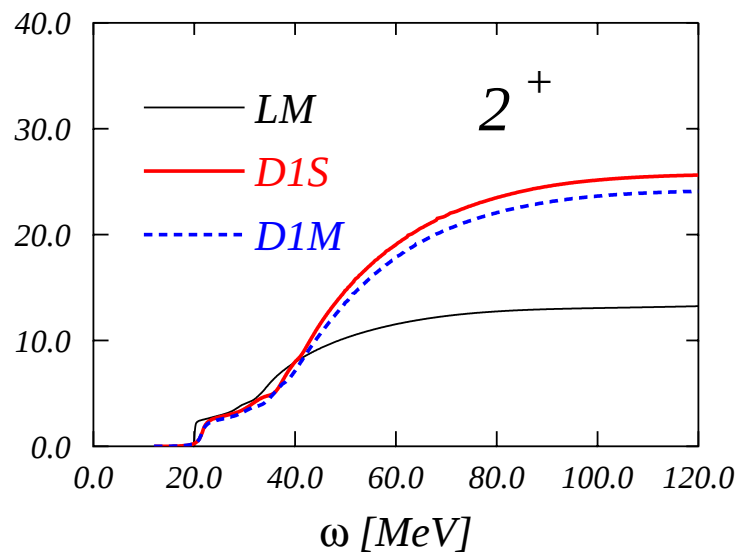
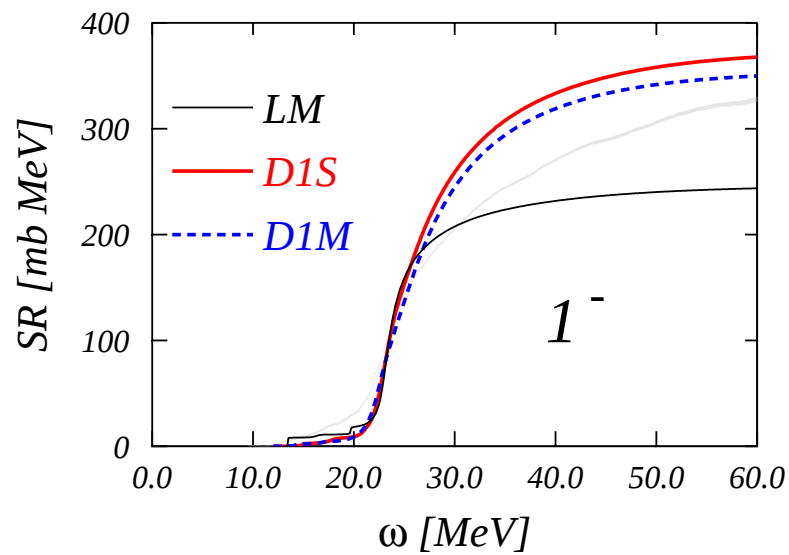
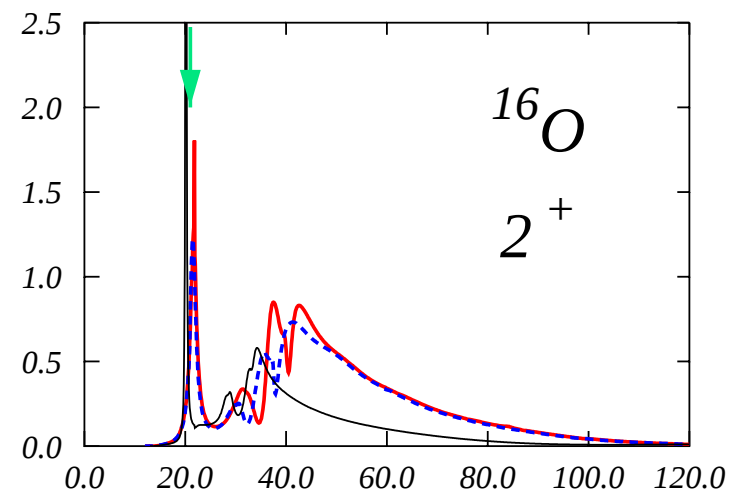
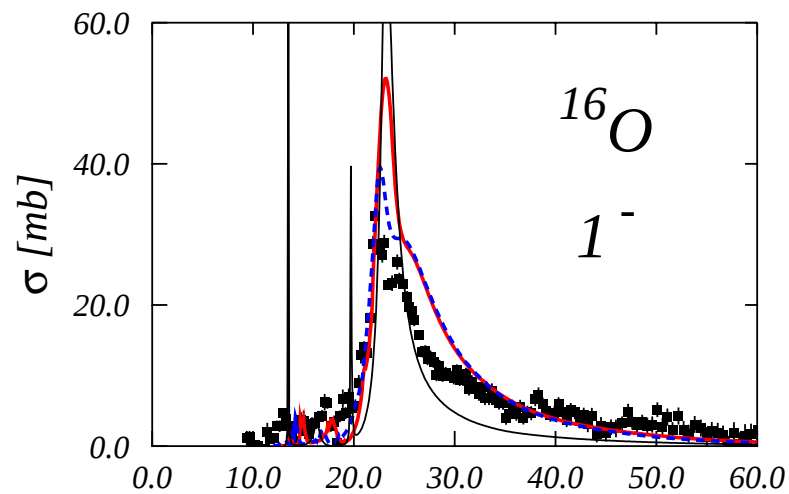
Centroid energies in MeV

$\epsilon_{ph}^{\text{max}}$	20	50	200	250	cont.
D1S	24.06	27.80	28.27	28.25	28.58
D1M	24.74	27.82	28.25	28.23	28.57



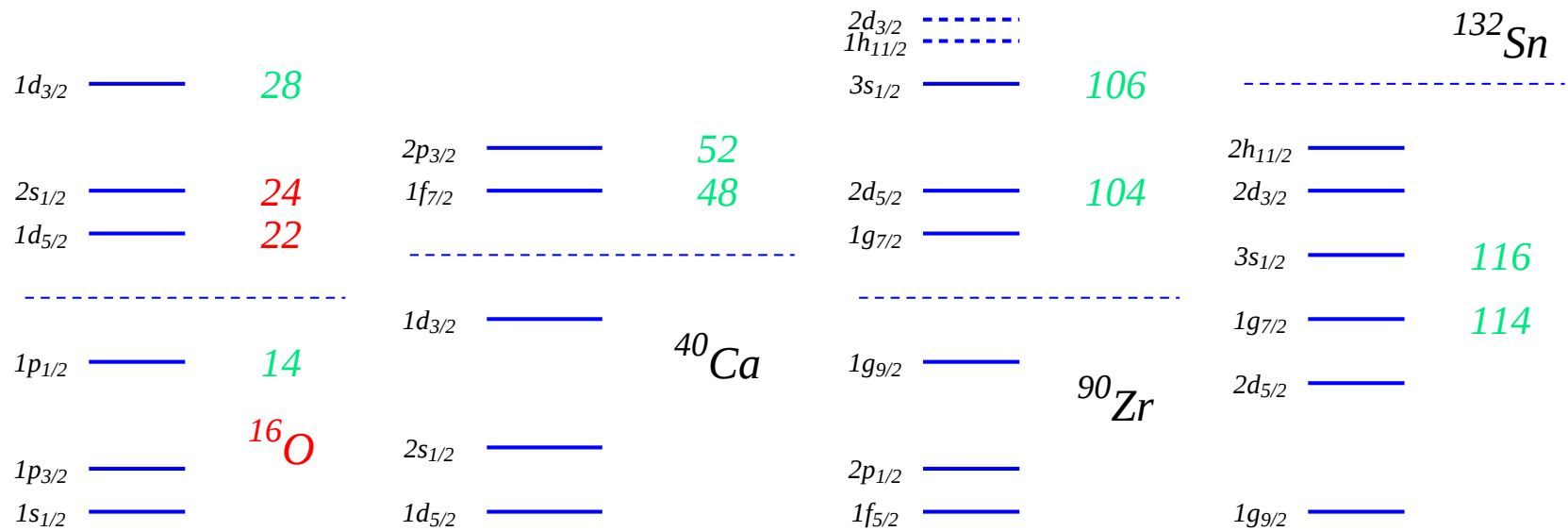
1^- data: J. Ahrens et al., Nucl. Phys. A 251 (1975) 479.

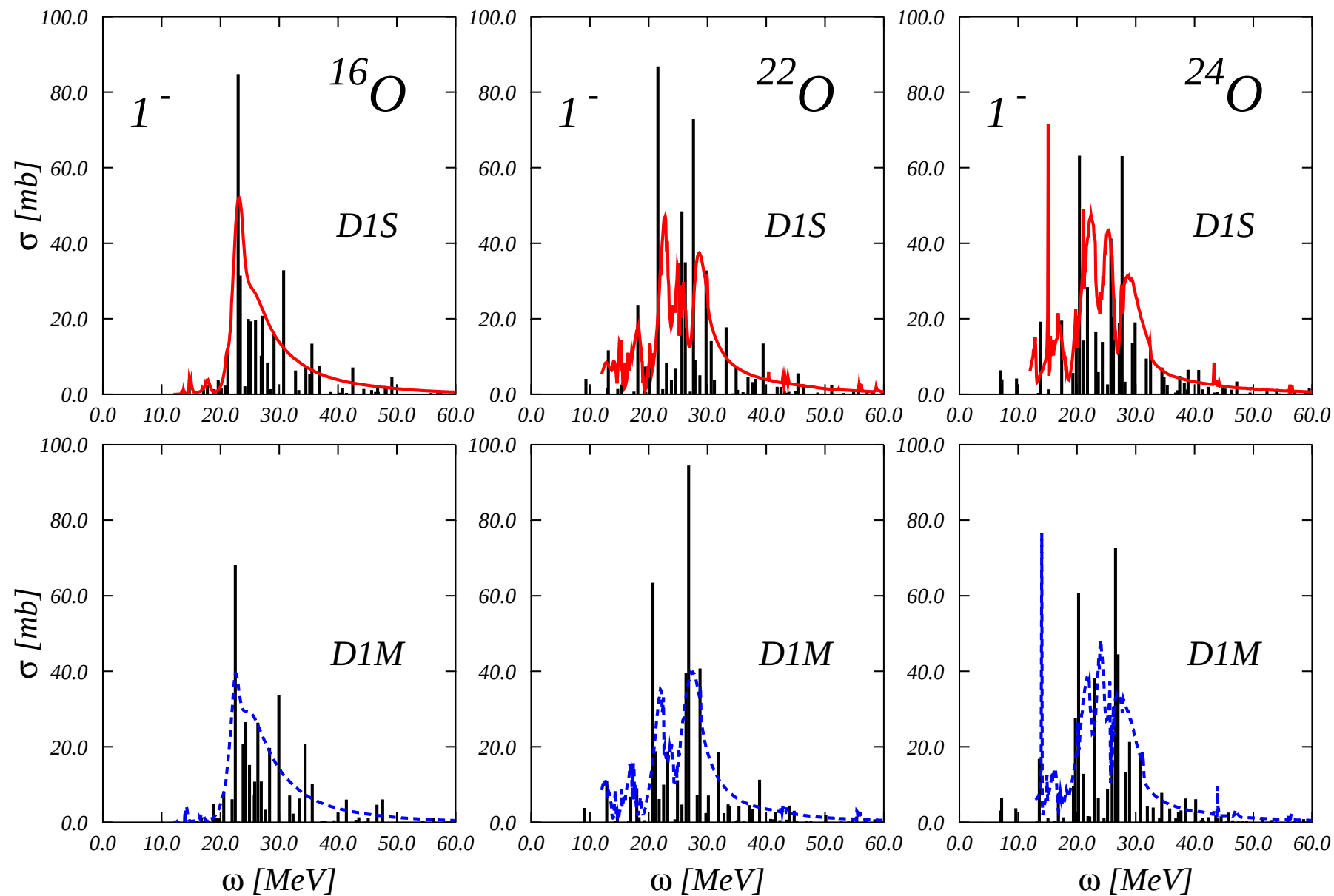
2^+ data: K. T. Knöpfke et al., Phys. Rev. Lett. 35 (1975) 779

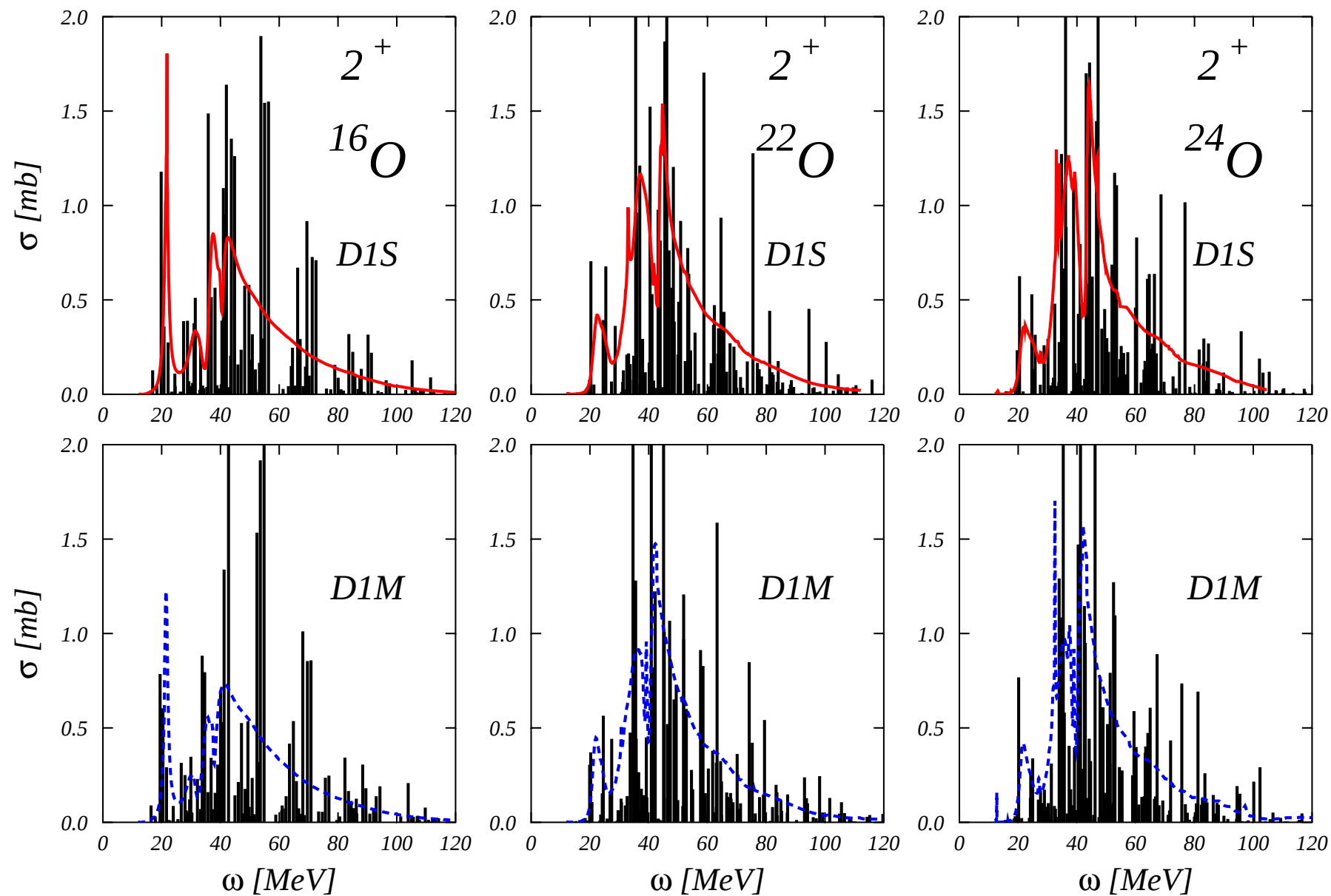


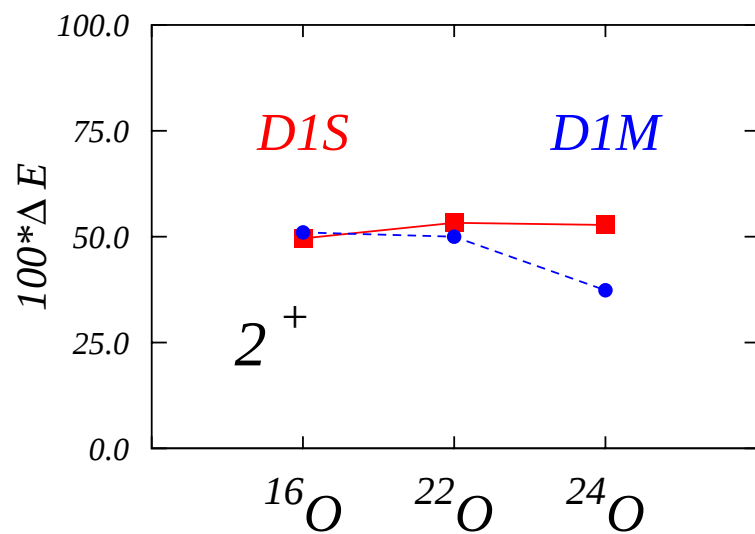
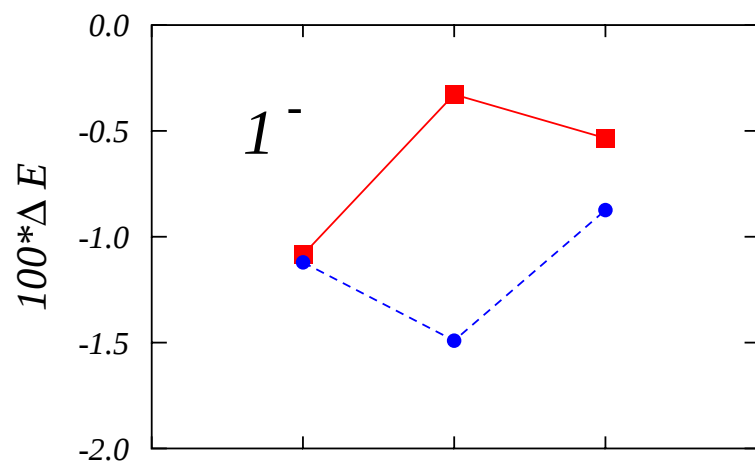
1^- data: J. Ahrens et al., Nucl. Phys. A 251 (1975) 479.

2^+ data: K. T. Knöpfke et al., Phys. Rev. Lett. 35 (1975) 779





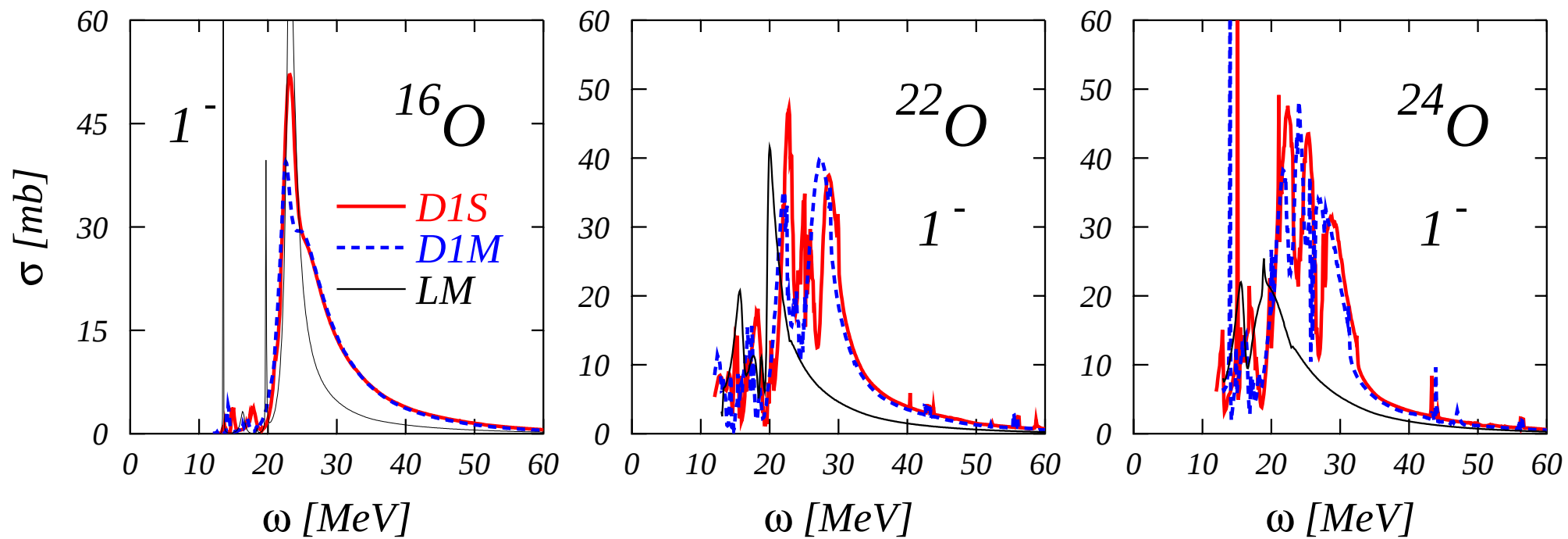




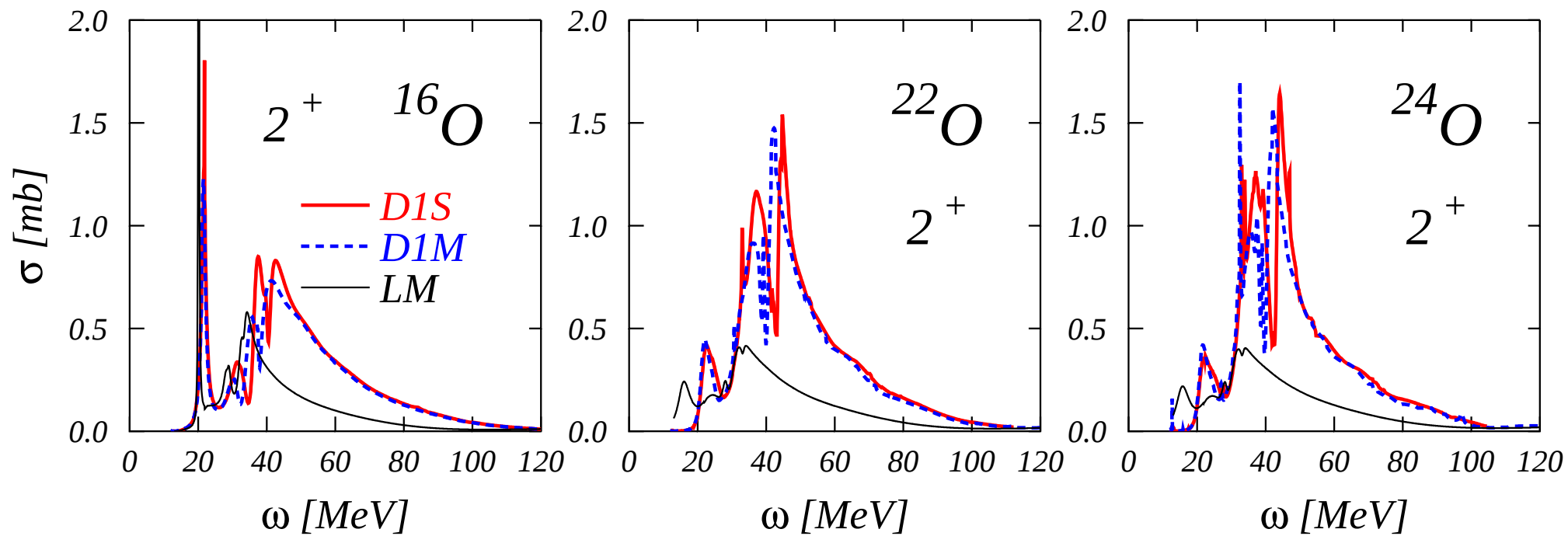
$$\Delta E = \frac{E^{\text{dis}} - E^{\text{con}}}{E^{\text{con}}}$$

Centroid energies in MeV

	^{16}O	^{22}O	^{24}O
1^-			
D1S(dis)	28.27	27.34	26.08
D1S(con)	28.58	27.43	26.18
D1M(dis)	28.24	27.09	25.99
D1M(con)	28.56	27.50	26.31
2^+			
D1S(dis)	67.99	68.77	67.54
D1S(con)	45.45	44.87	44.21
D1M(dis)	69.09	67.50	60.07
D1M(con)	45.76	45.00	43.74



Centroid energies in MeV			
	D1S	D1M	LM
^{16}O	28.58	28.56	26.00
^{22}O	27.43	27.50	23.52
^{24}O	26.18	26.31	23.60

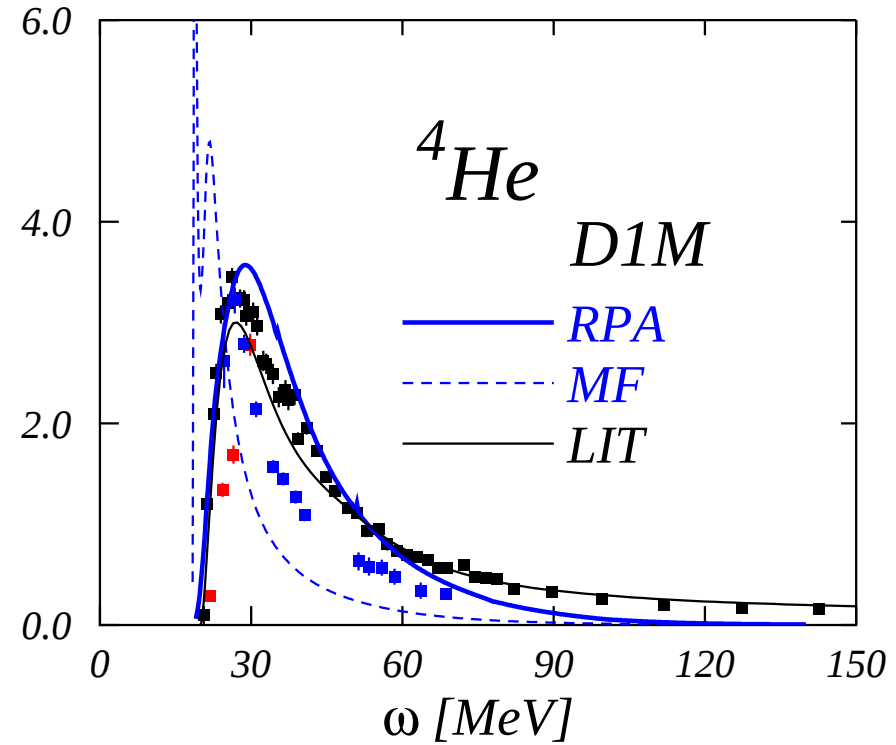
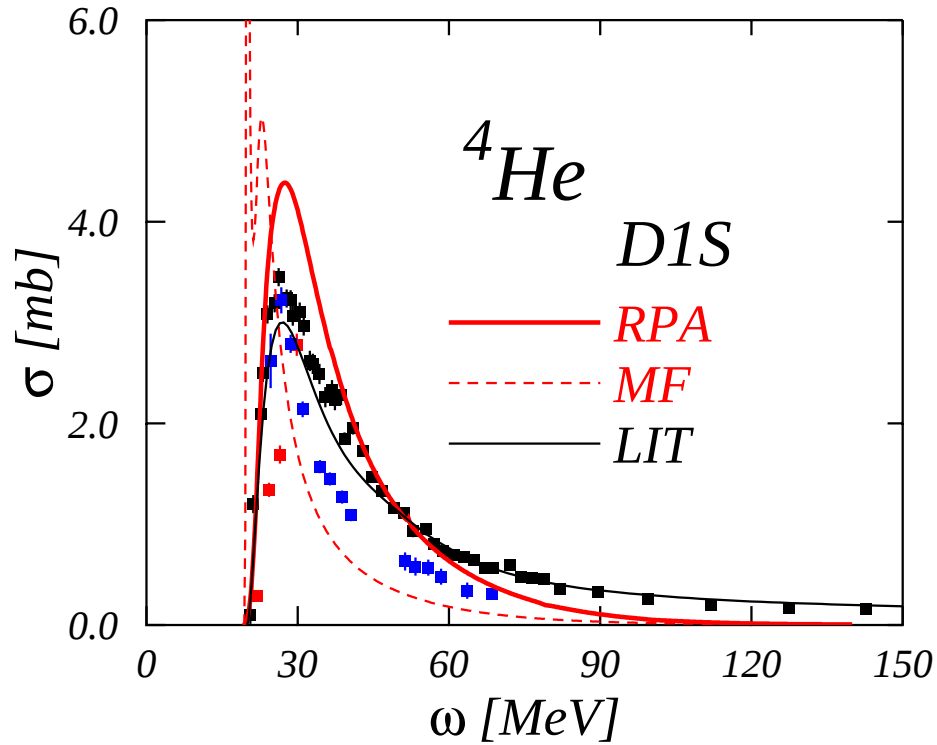


Centroid energies in MeV			
	D1S	D1M	LM
^{16}O	45.45	45.76	40.19
^{22}O	44.87	45.00	43.70
^{24}O	44.21	43.74	44.86

^4He

$E(\text{D1S}) = 30.28 \text{ MeV}$

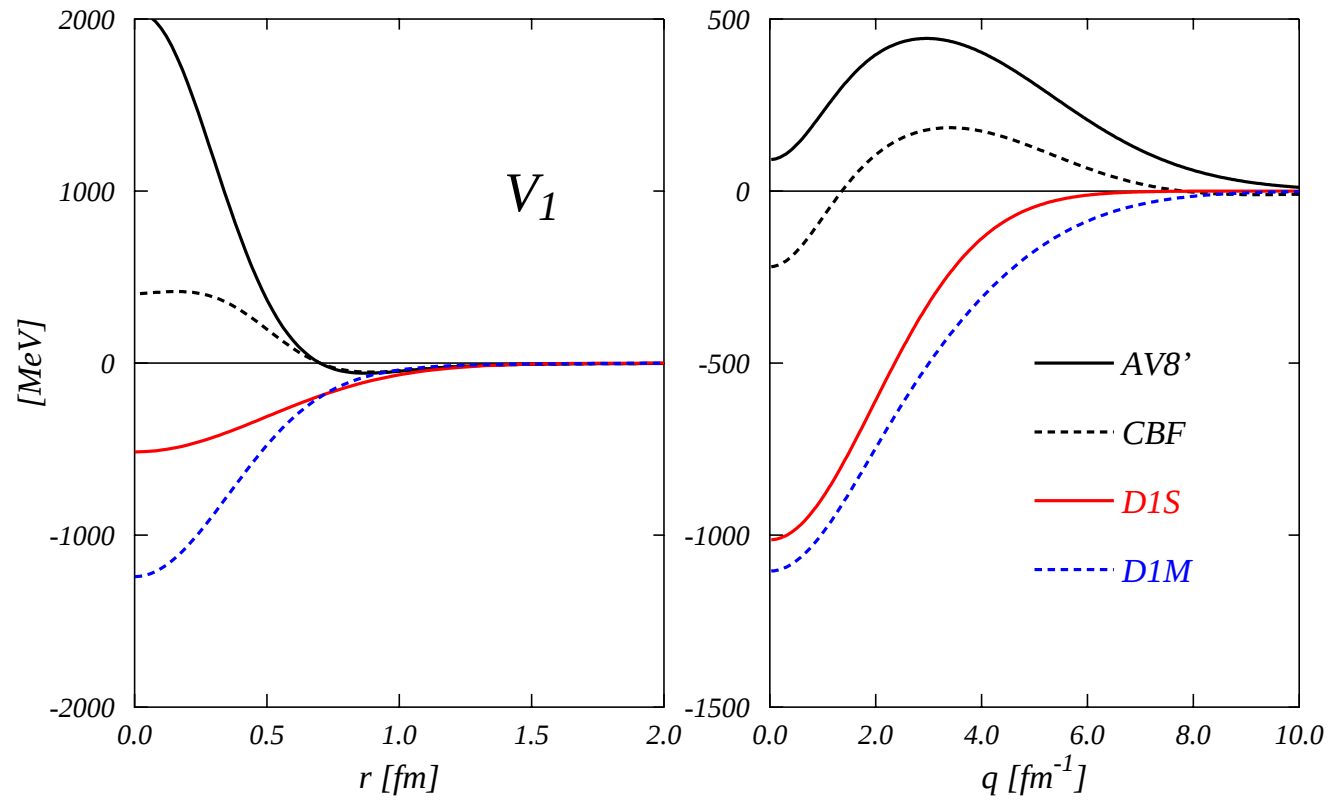
$E(\text{D1M}) = 29.54 \text{ MeV}$



Data: T. Shima et al., Phys. Rev. C 72 (2005) 044004, B. Nilsson et al., Phys. Lett. B 626 (2005) 65,
Yu. M. Arkatov et al. Yad. Konst. 4 (1979) 55.

LIT: D. Gazit et al., Phys. Rev. Lett. 96 (2006) 112301, G. Orlandini, priv. comm.

Scalar terms of the interaction



CBF correlation from

F. Arias de Saavedra, C. Bisconti, G. Co' and A. Fabrocini, Phys. Rep. 450 (2007) 450