Catania, Sept. 15 - 16, 2011

Study of exotic nuclei with self-consitent continuum RPA

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Self-consistent RPA approach

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

Same interaction 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

Two parameterizations

- 14 parameters chosen with a fit of about 2000 nuclear binding energies and 200 charge radii.

-D1S: J. F. Berger et al., Comp. Phys. Comm. 63 (1991) 365

-D1M: S. Goriely et al., Phys. Rev. Lett. 102 (2009) 252501

Continuum in RPA

(A simplified presentation limited to TDA)

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

Definition of a new unknown

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

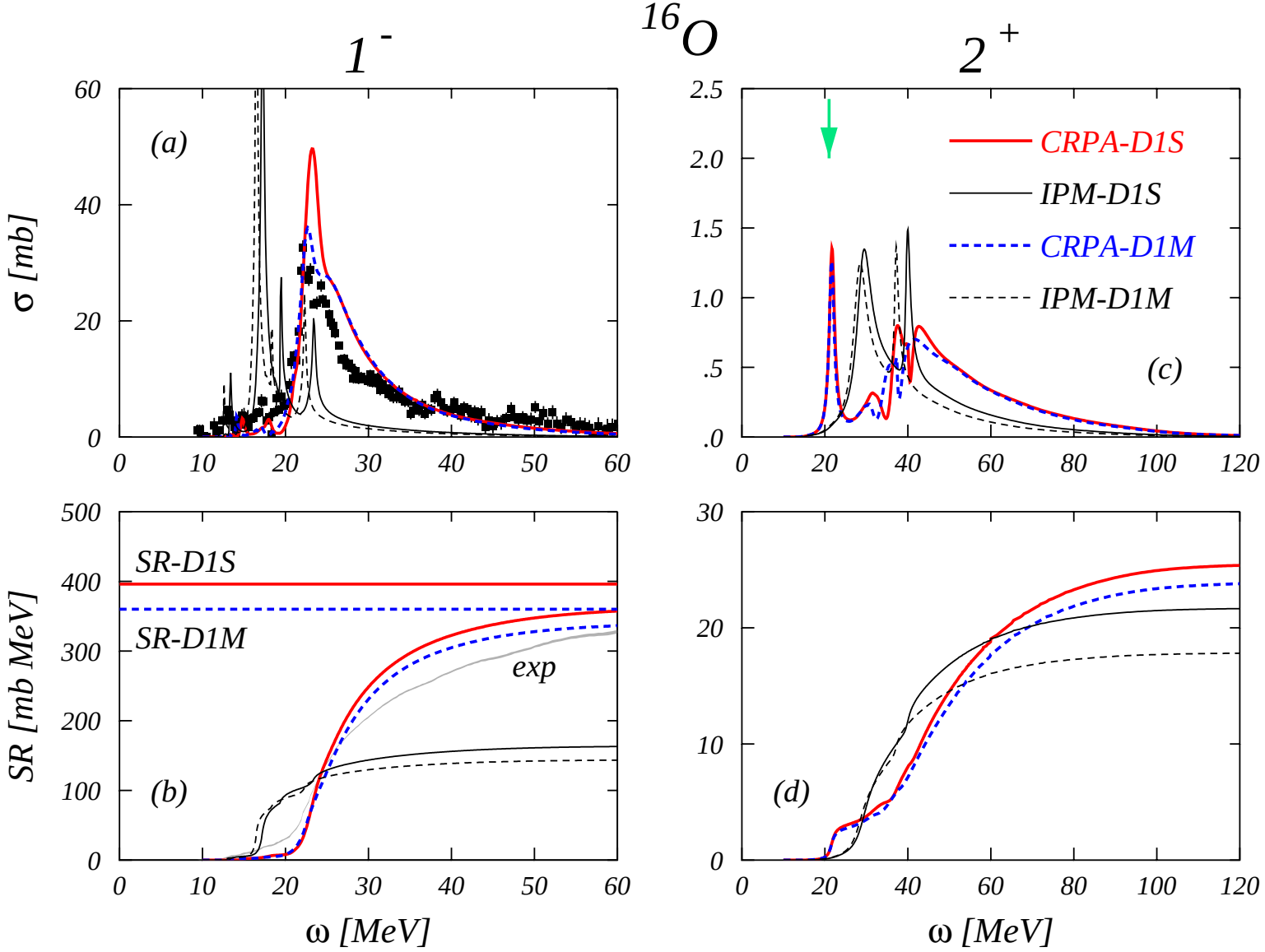
A new equation to be solved

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

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

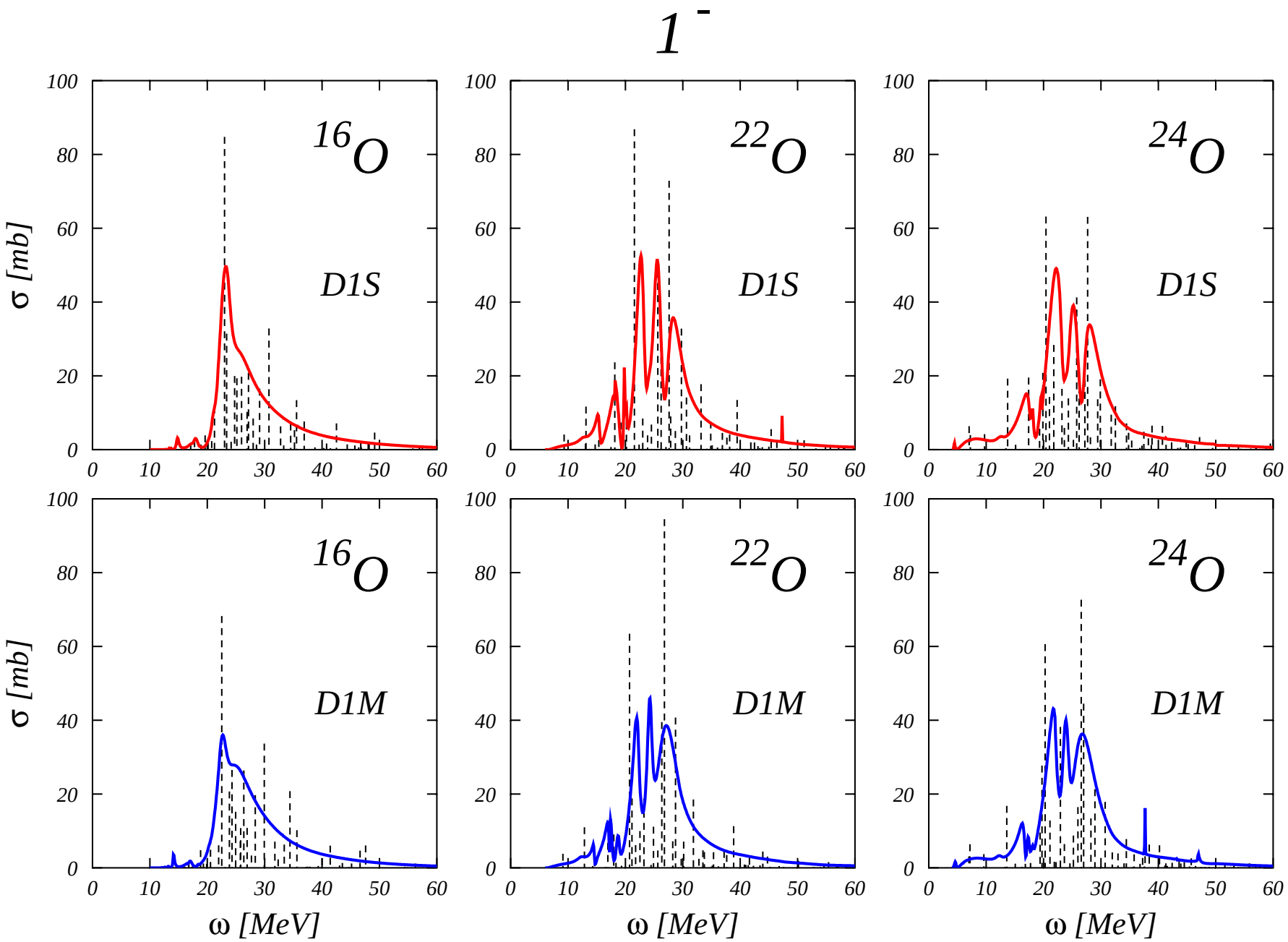
Details in

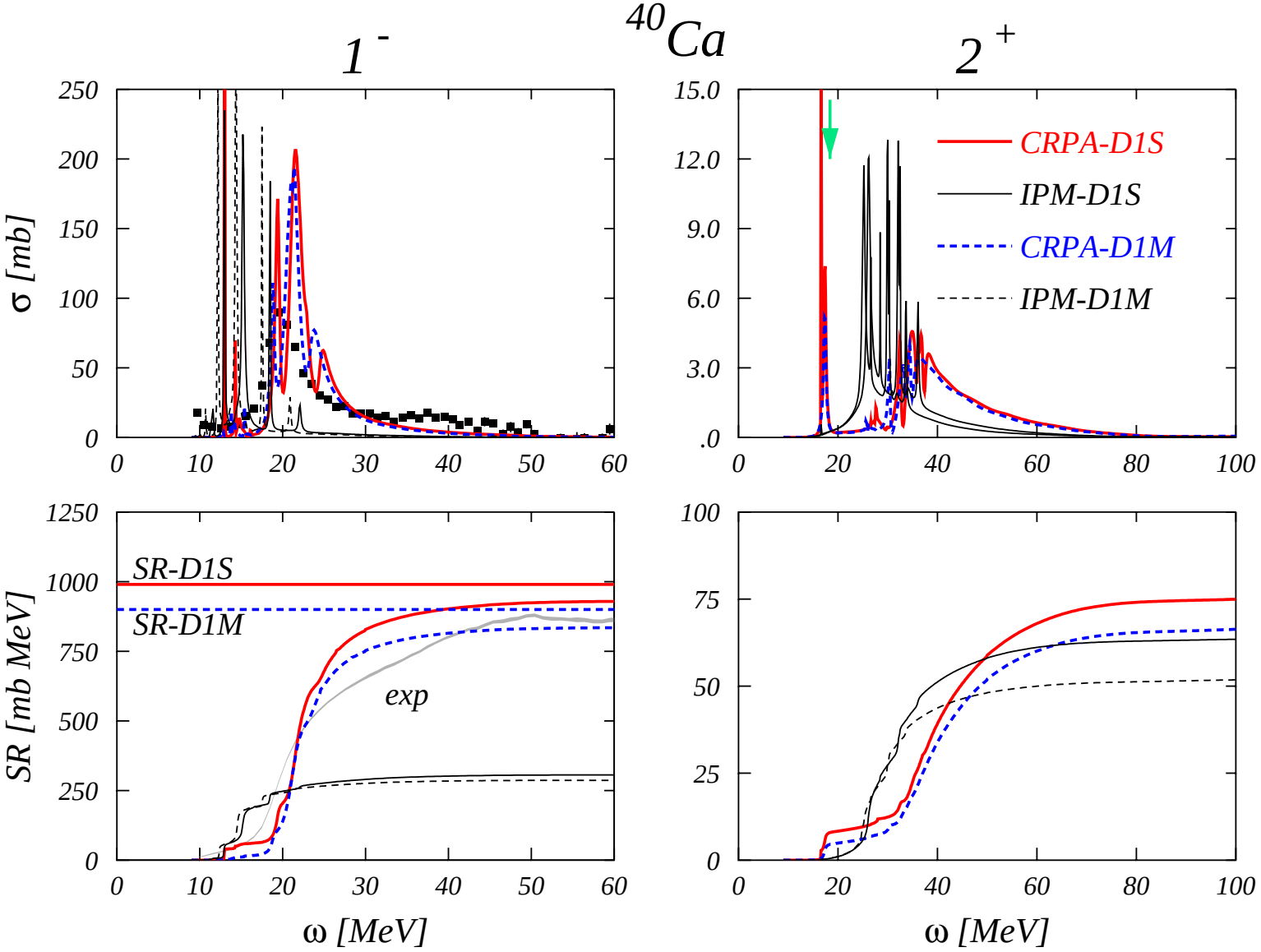
V. De Donno et al., Phys. Rev. C 83 (2011) 044324



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

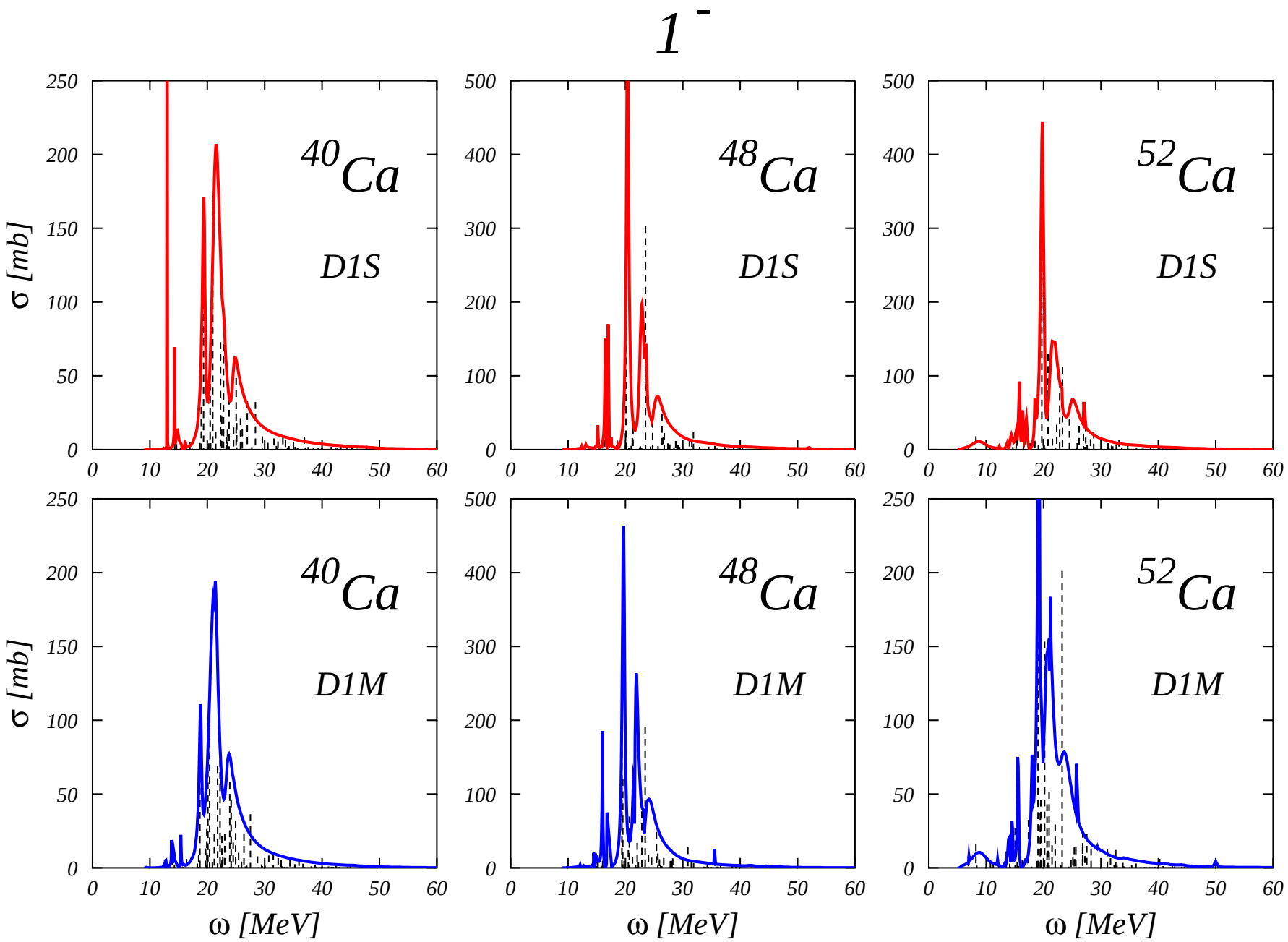
2^+ data: K. T. Knöpfke et al., Phys. Rev. Lett. 35 (1975) 779


1-
16O
22O
24O
D1S
D1M
σ [mb]
ω [MeV]
0
20
40
60
80
100
0
10
20
30
40
50
60



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

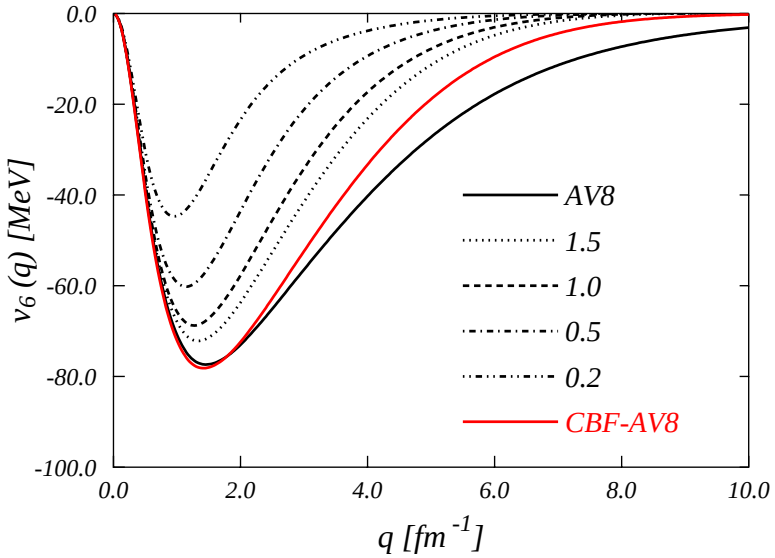

1-
40Ca
D1S
48Ca
D1S
52Ca
D1S
40Ca
D1M
48Ca
D1M
52Ca
D1M
σ [mb]
σ [mb]
ω [MeV]
ω [MeV]
ω [MeV]

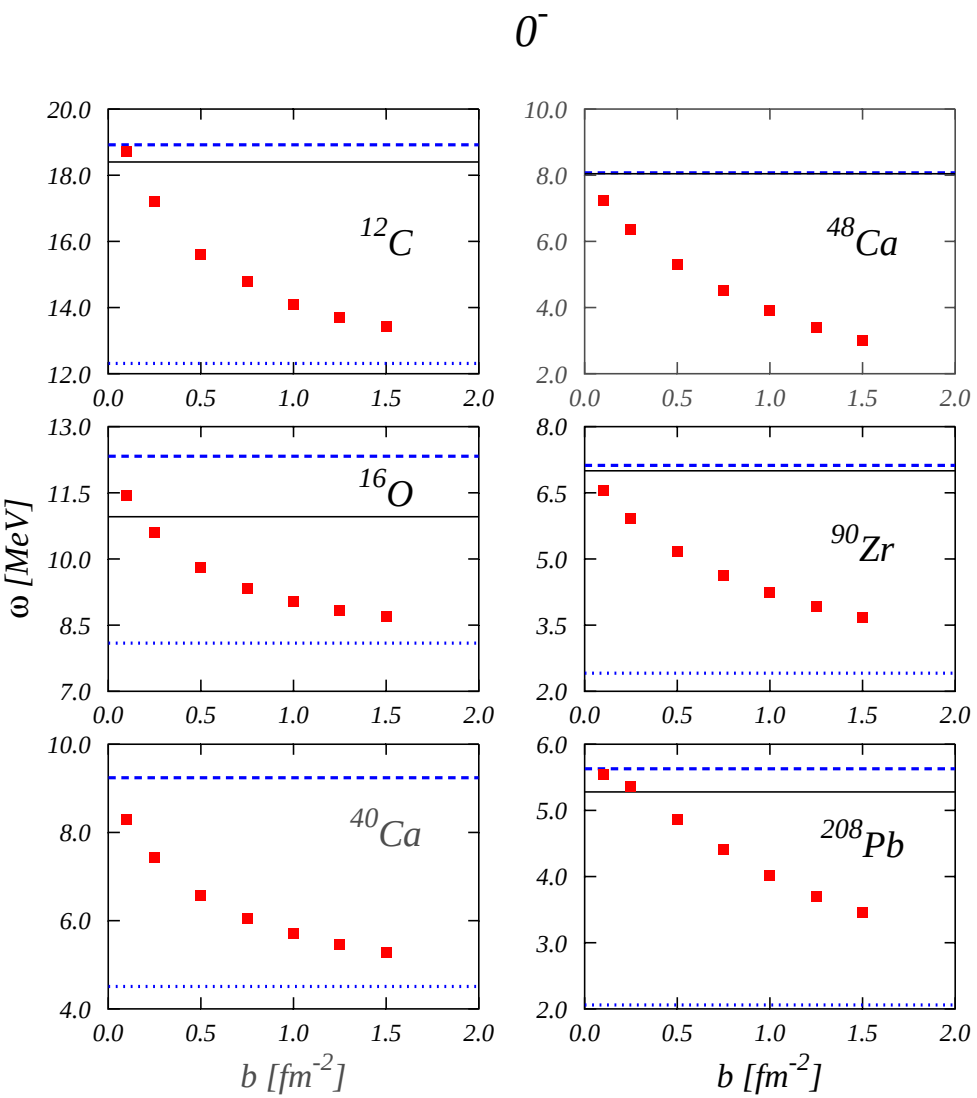
Magnetic excitations

Tensor-isospin term added to Gogny forces

$$v_6(r) = v_{6,AV18}(r)[1 - exp(-br^2)]$$

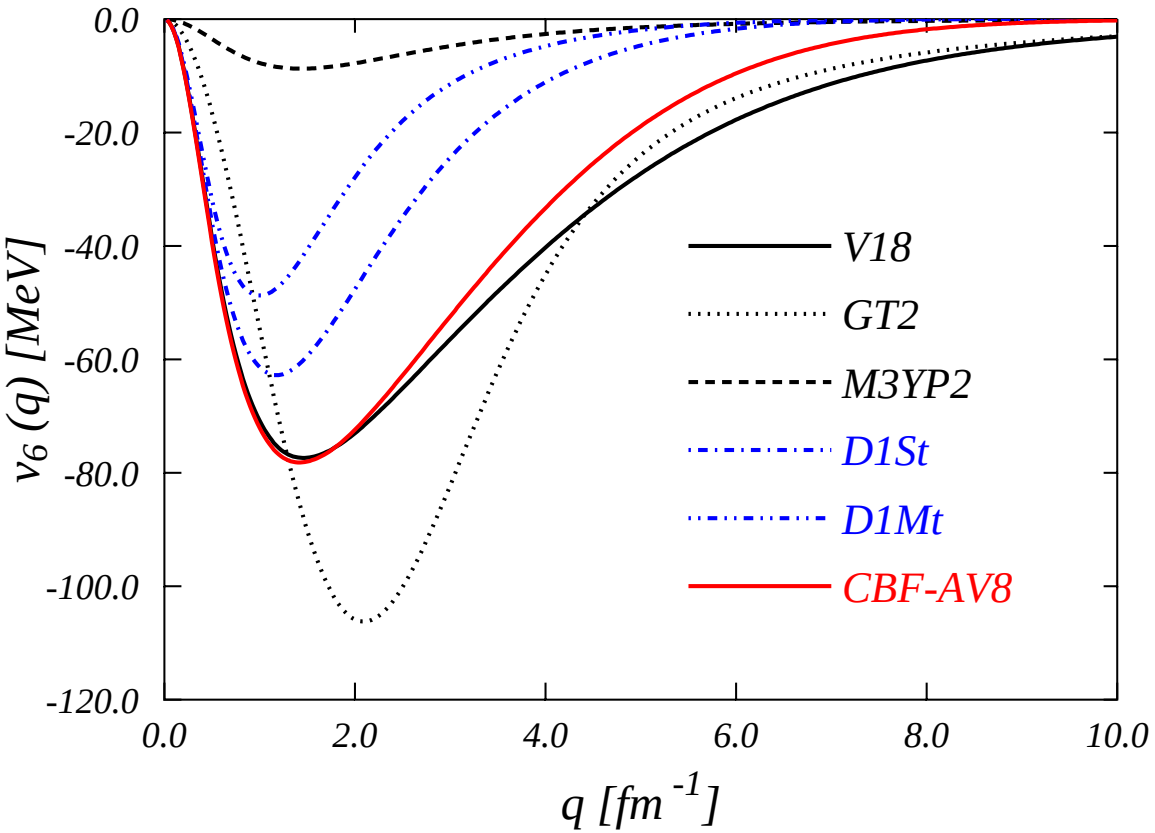
b - free parameter

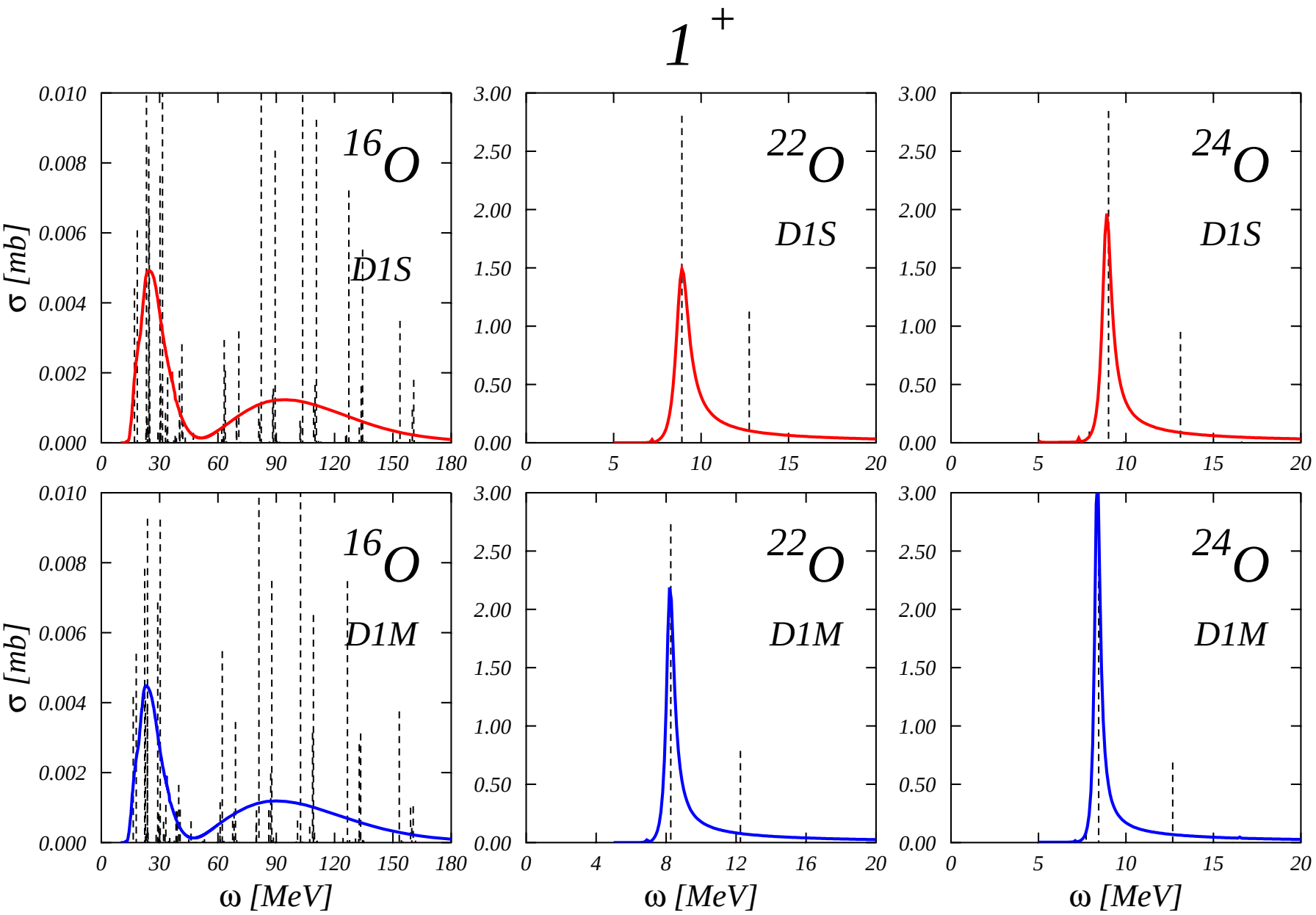


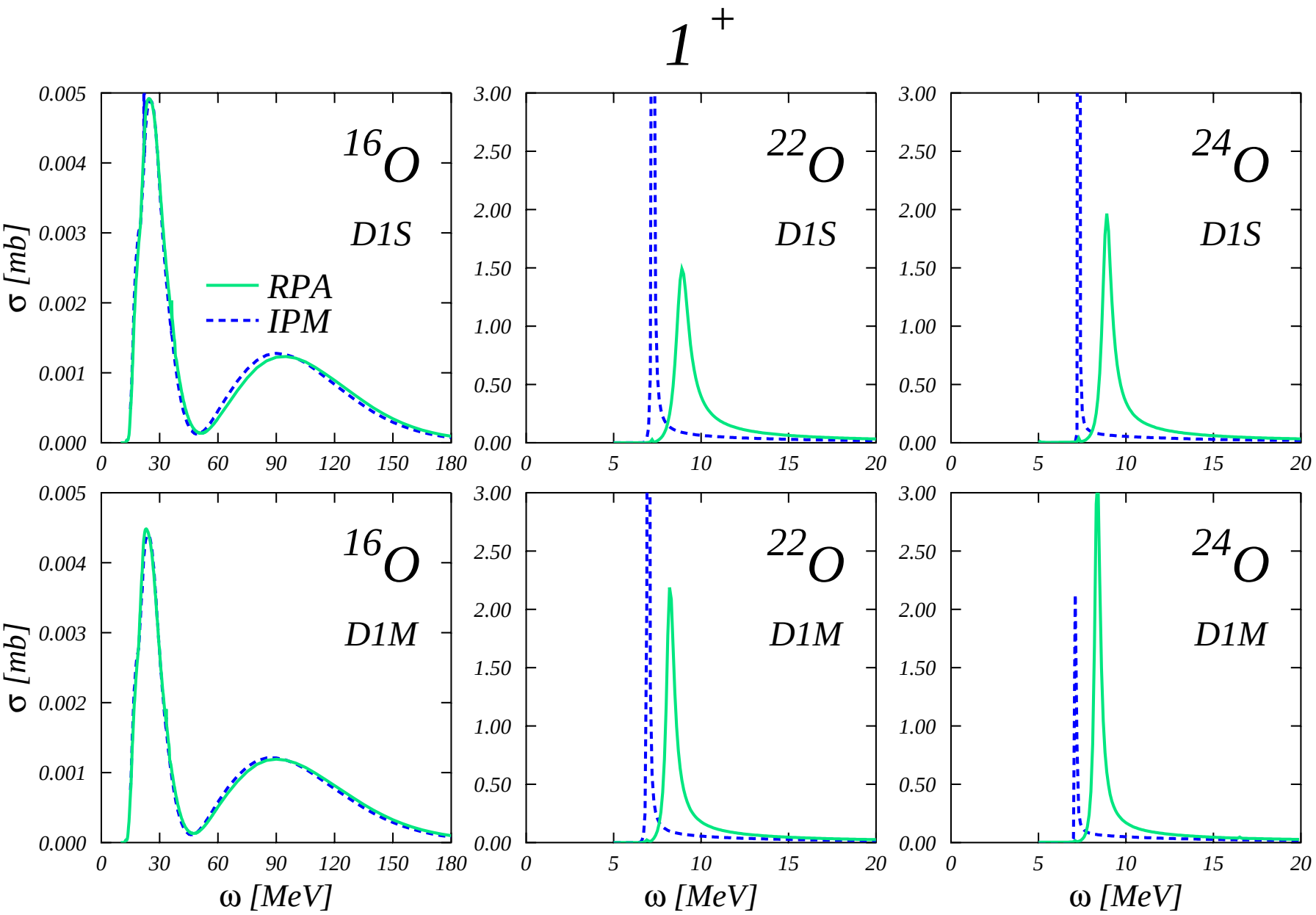


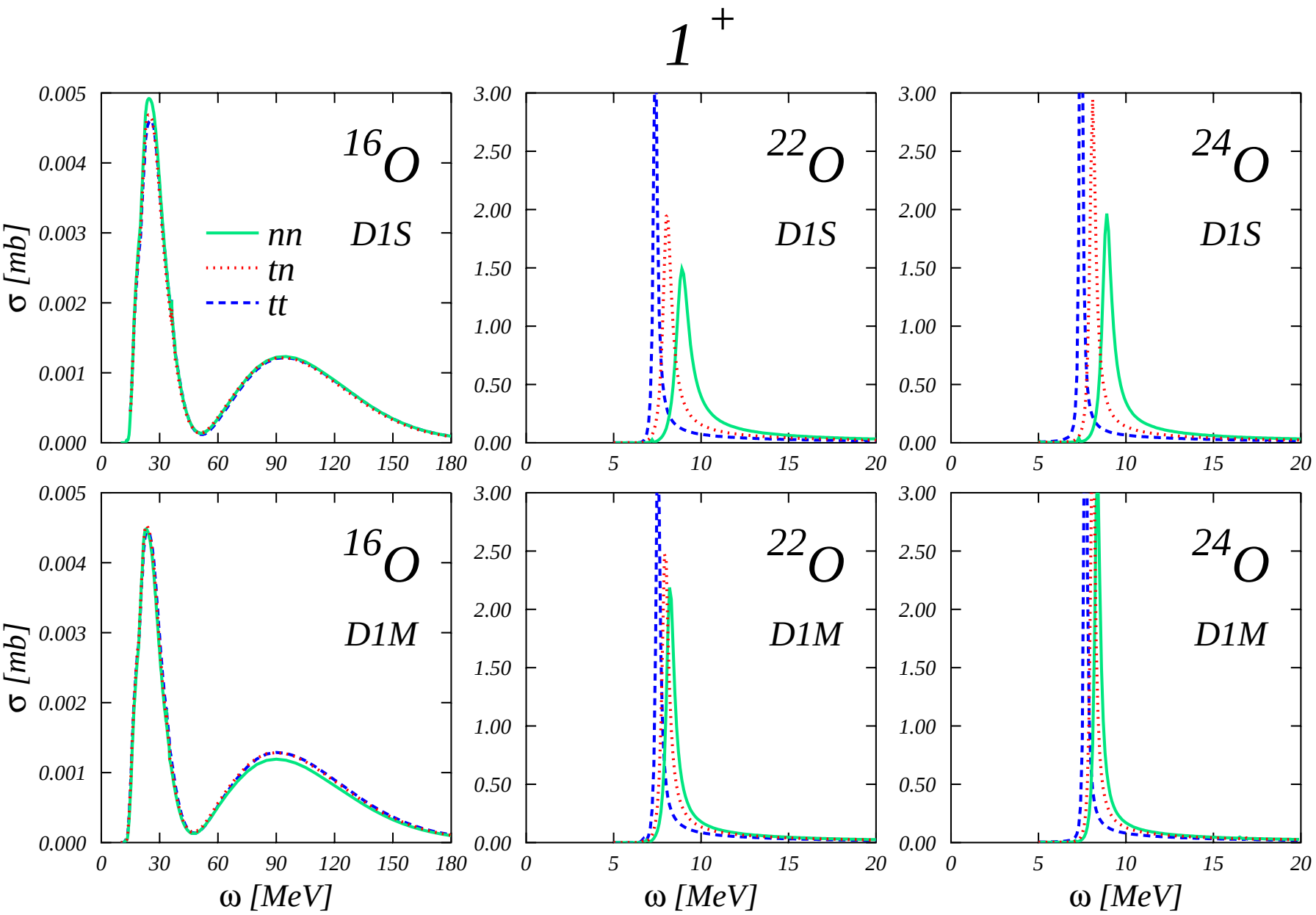
The value of b has been chosen to reproduce the experimental value of the exitation energy of the fist 0^- in ^{16}O.

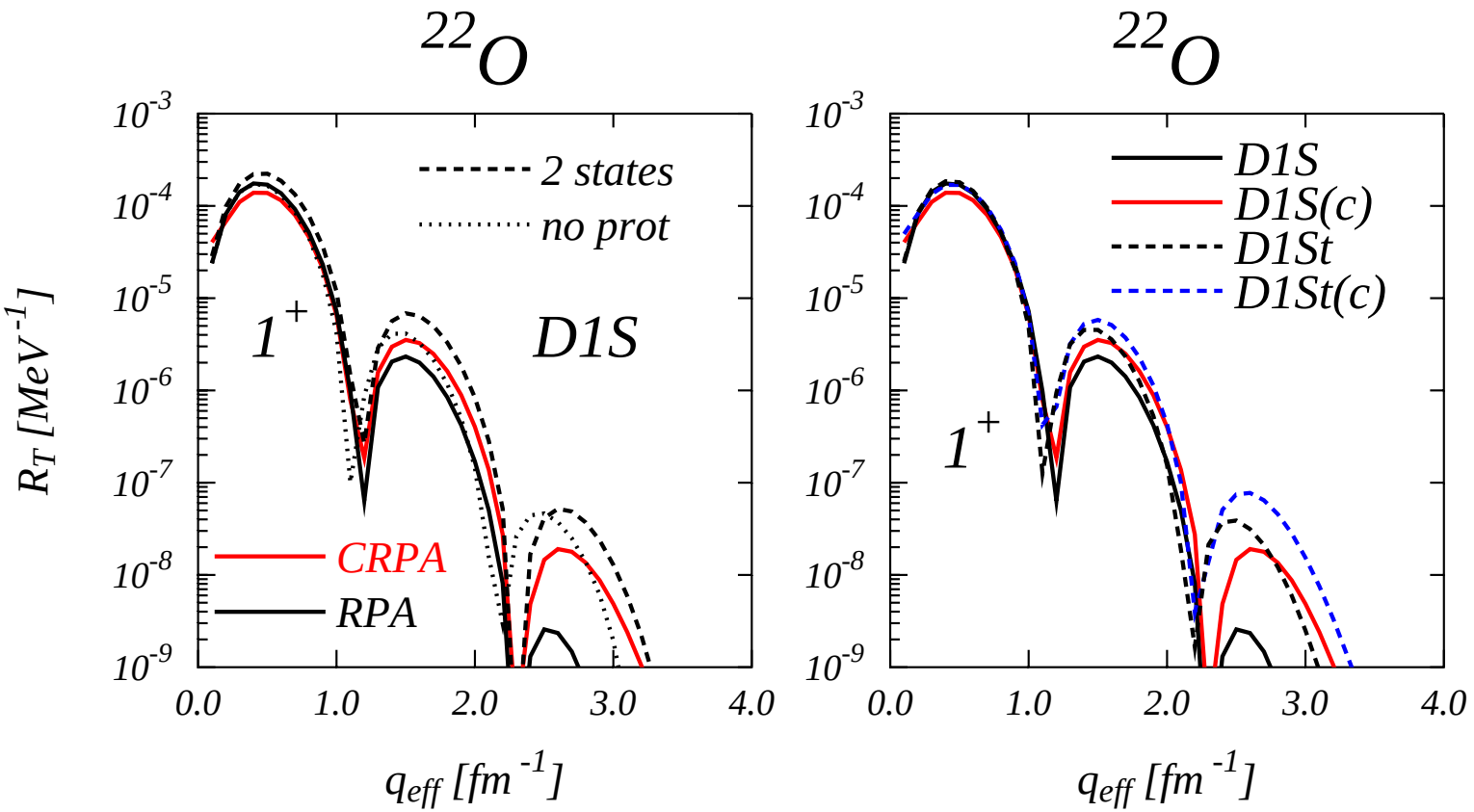
Only the value of the spin-orbit term of the interaction has been modified to reproduce the experimental splitting between the energies of the $1p_{3/2}$ and $1p_{1/2}$ neutron single particle states in ^{16}O.

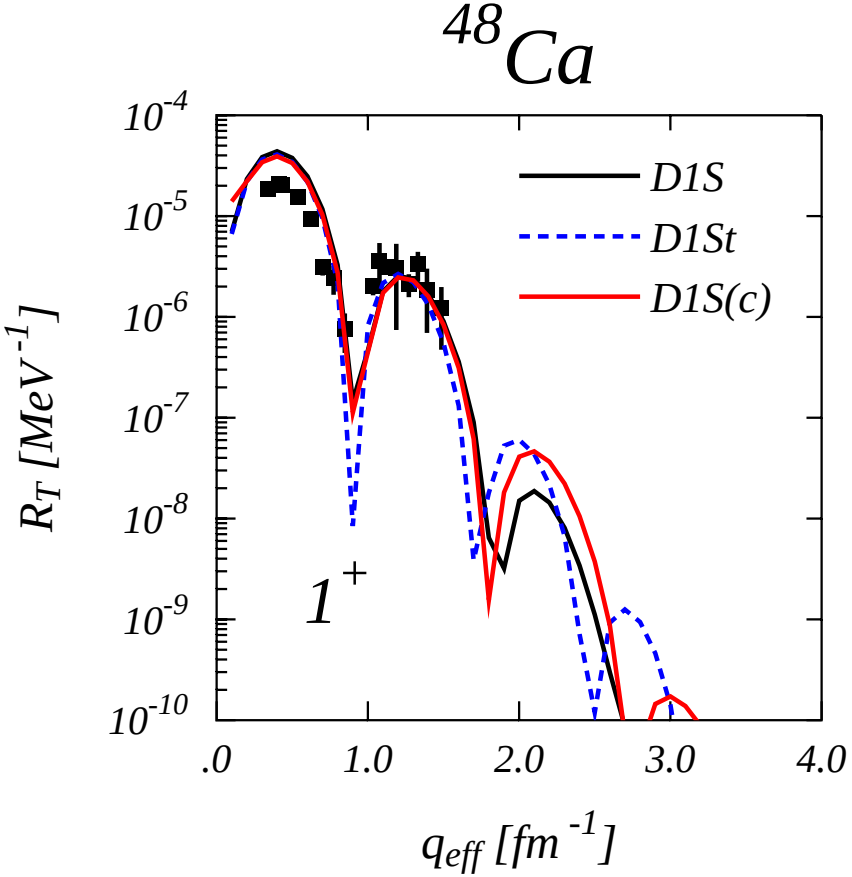

0.0
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
0.0
2.0
4.0
6.0
8.0
10.0
v_6 (q) [MeV]
q [fm^{-1}]
V18
GT2
M3YP2
D1St
D1Mt
CBF-AV8


1+
16O
D1S
22O
D1S
24O
D1S
16O
D1M
22O
D1M
24O
D1M
σ [mb]
σ [mb]
ω [MeV]
ω [MeV]
ω [MeV]


1+
16O
D1S
RPA
IPM
22O
D1S
24O
D1S
16O
D1M
22O
D1M
24O
D1M
σ [mb]
ω [MeV]
0.000
0.001
0.002
0.003
0.004
0.005
0.00
0.50
1.00
1.50
2.00
2.50
3.00
0
30
60
90
120
150
180
5
10
15
20


1+
16O
D1S
nn
tn
tt
22O
D1S
24O
D1S
16O
D1M
22O
D1M
24O
D1M
σ [mb]
ω [MeV]
0.005
0.004
0.003
0.002
0.001
0.000
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
30
60
90
120
150
180
5
10
15
20


^{22}O
^{22}O
R_T [MeV^{-1}]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.0
1.0
2.0
3.0
4.0
q_{eff} [fm^{-1}]
2 states
no prot
1^+
D1S
CRPA
RPA
D1S
D1S(c)
D1St
D1St(c)



ω [MeV]

10.16 D1S

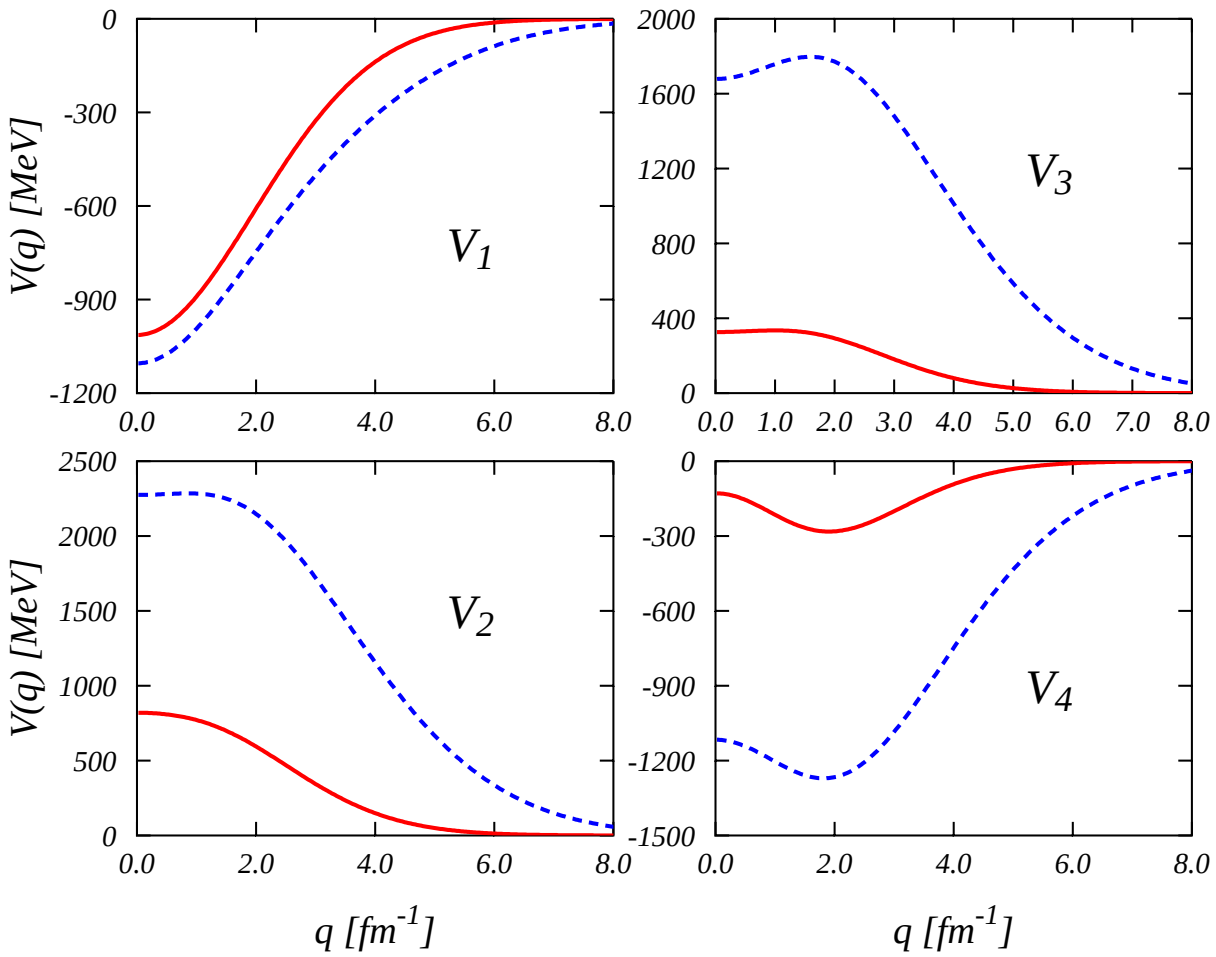
8.56 D1St

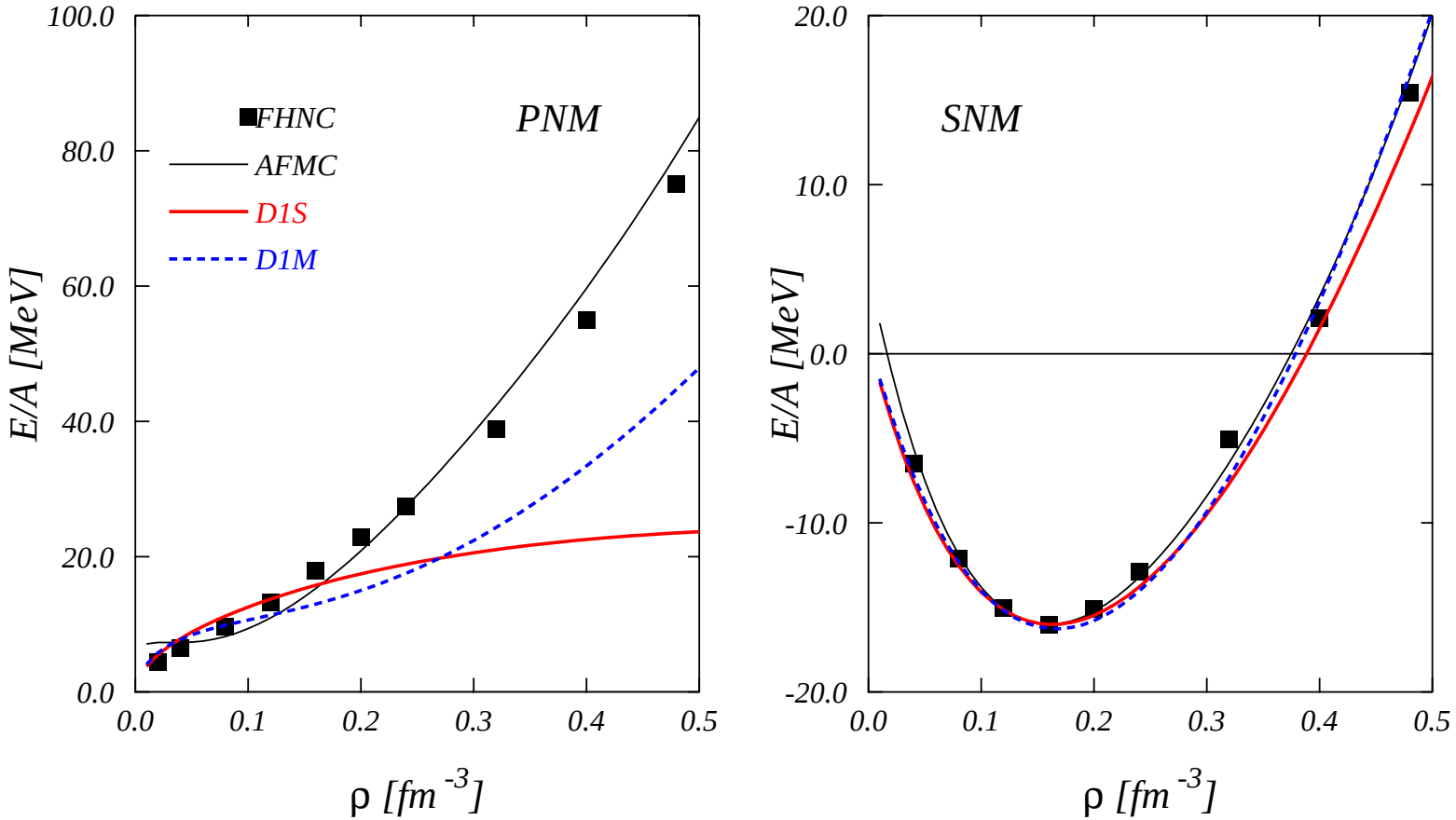
10.25 D1S(c)

Conclusions

- Continuum required to have a good description of the dynamics of the excited states.
- Fragmentation of the electric giant resonance due to the neutrons in excess.
- Magnetic states well excited in nuclei with neutron excess.
- Single particle picture inadequate to describe magnetic states.
- Tensor term plays an important role in the description of magnetic excitations.

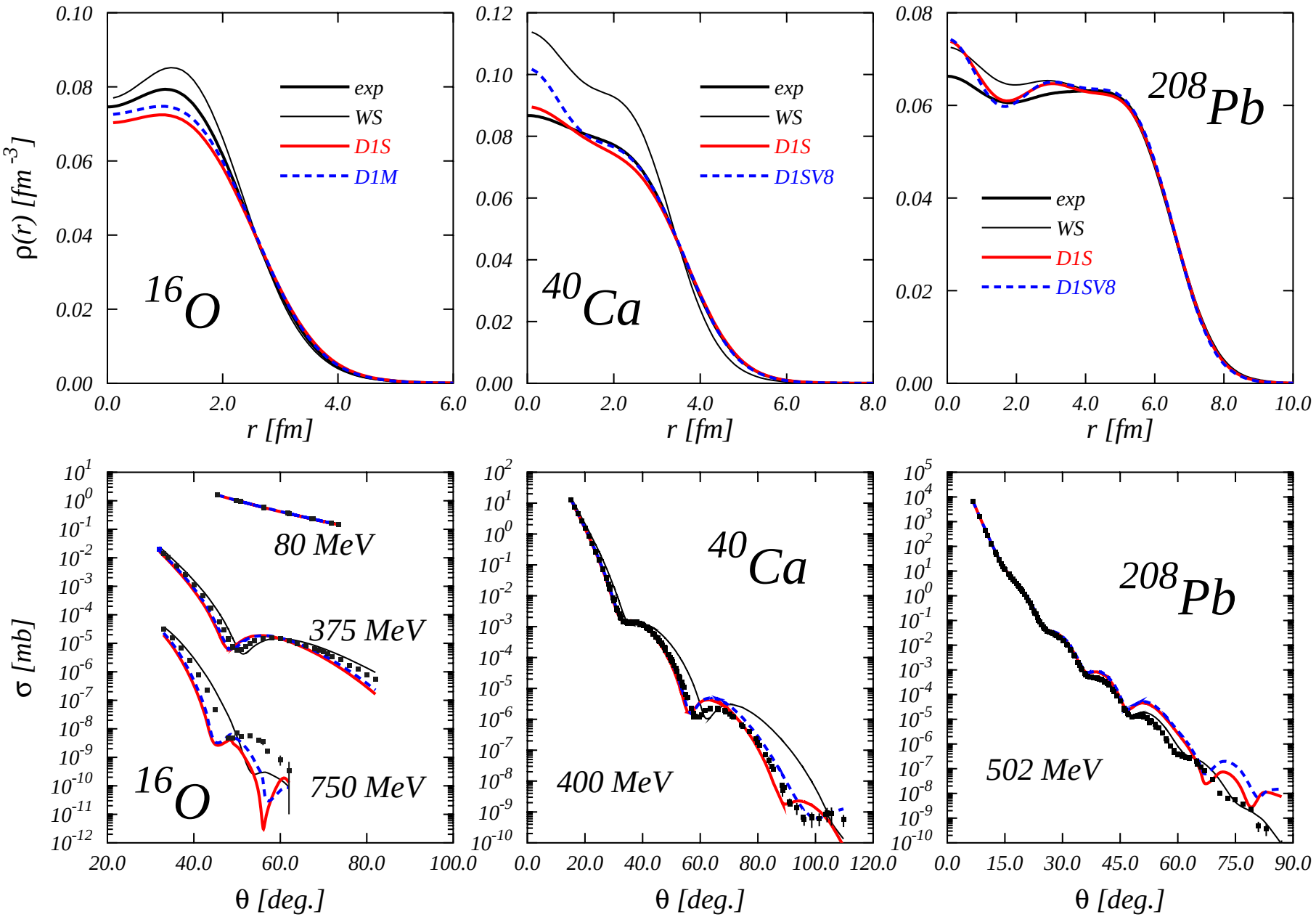
SPARE SLIDES

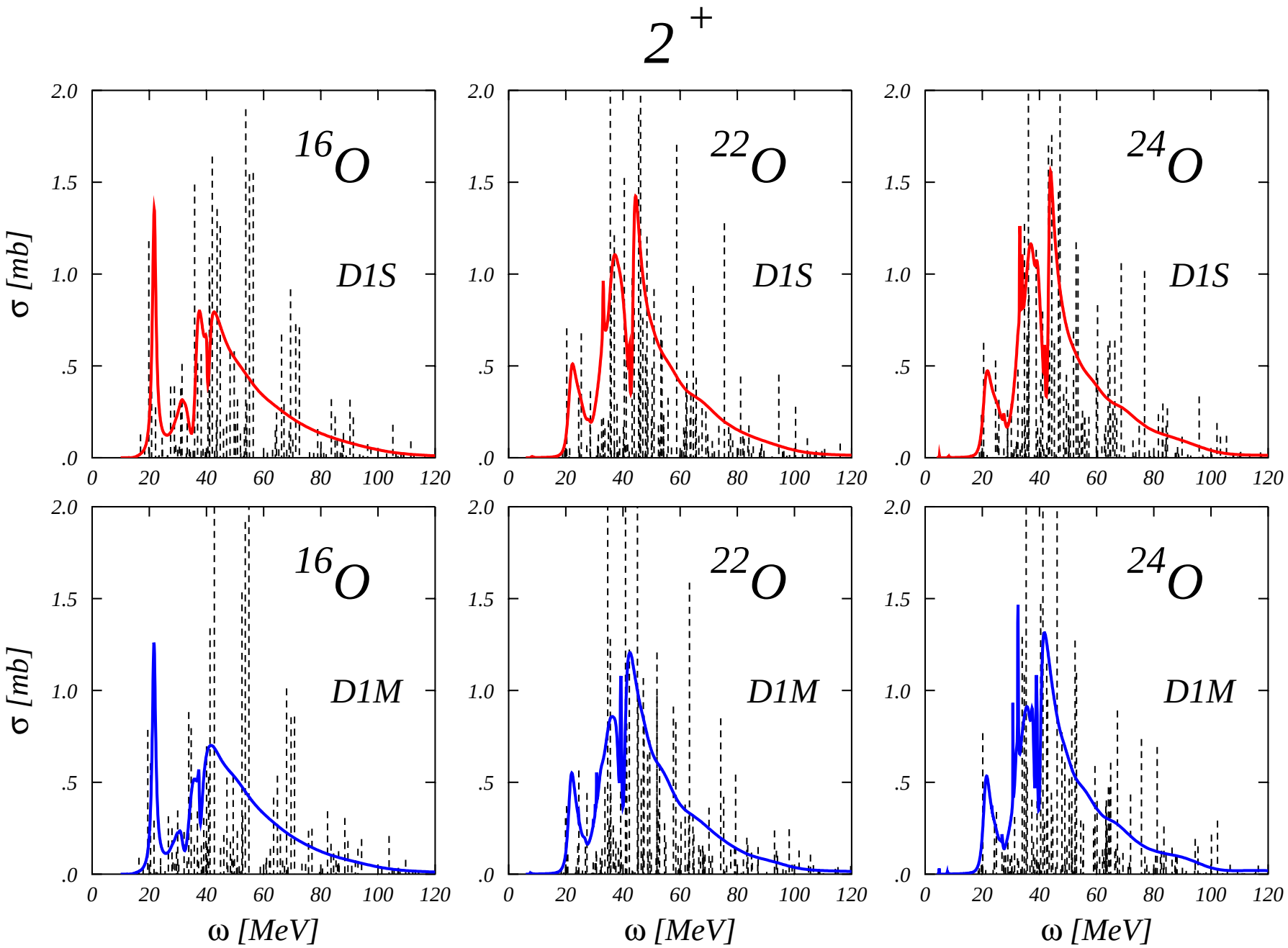

V(q) [MeV]
V1
V3
V2
V4
q [fm-1]
q [fm-1]
D1S
D1M



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

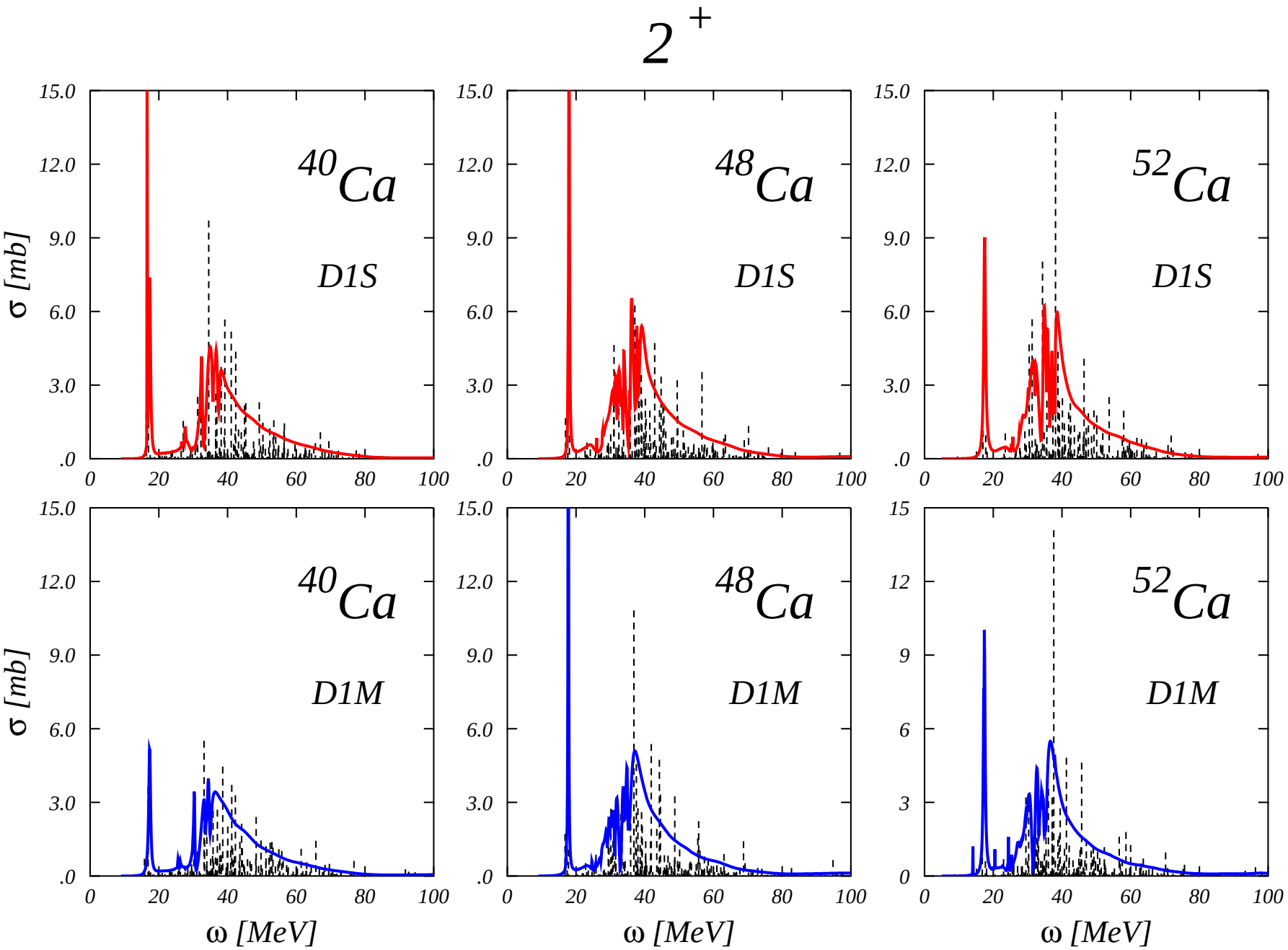
AFMC: S. Gandolfi et al., Mon. Not. Roy. Astron. Soc. 404 (2010) L35


ρ(r) [fm^-3]
r [fm]
exp
WS
D1S
D1M
D1SV8
16O
40Ca
208Pb
σ [mb]
θ [deg.]
80 MeV
375 MeV
750 MeV
400 MeV
502 MeV


2 +
16O
D1S
22O
D1S
24O
D1S
16O
D1M
22O
D1M
24O
D1M
σ [mb]
σ [mb]
ω [MeV]
ω [MeV]
ω [MeV]
0
20
40
60
80
100
120
.0
.5
1.0
1.5
2.0

Centroid energies in MeV

	^{16}O	^{22}O	^{24}O
1^-			
D1S(dis)	26.34	24.87	22.82
D1S(con)	27.17	25.11	23.07
D1M(dis)	26.36	24.72	22.81
D1M(con)	27.23	25.04	23.20
2^+			
D1S(dis)	28.43	32.91	31.58
D1S(con)	30.47	33.47	32.20
D1M(dis)	28.19	32.26	30.93
D1M(con)	30.51	33.06	31.06


2 +
40 Ca
D1S
48 Ca
D1S
52 Ca
D1S
40 Ca
D1M
48 Ca
D1M
52 Ca
D1M
σ [mb]
σ [mb]
ω [MeV]
ω [MeV]
ω [MeV]
15.0
12.0
9.0
6.0
3.0
.0
15
12
9
6
3
0
0
20
40
60
80
100

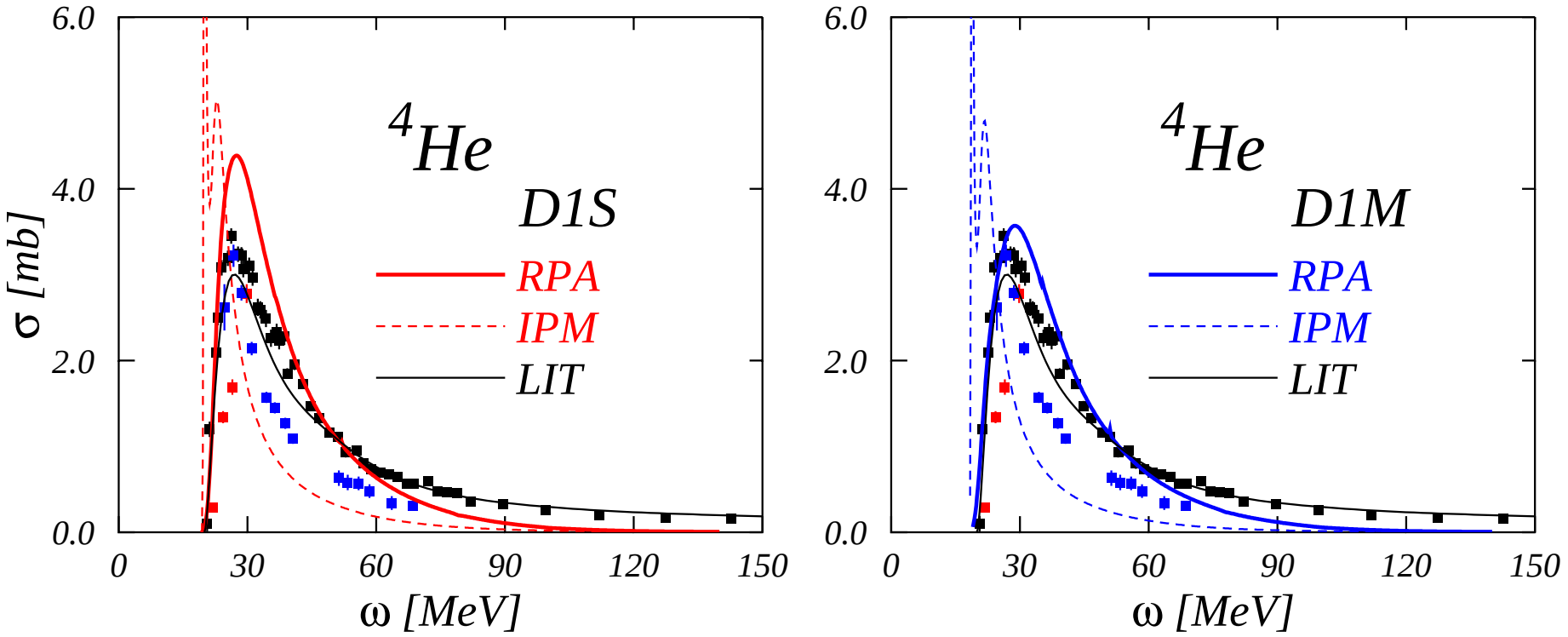
Centroid energies in MeV

	^{40}Ca	^{48}Ca	^{52}Ca
1^-			
D1S(dis)	22.37	22.27	20.56
D1S(con)	21.89	22.40	20.63
D1M(dis)	22.10	21.86	20.24
D1M(con)	22.42	21.77	20.33
2^+			
D1S(dis)	24.66	27.34	26.84
D1S(con)	25.02	26.89	26.14
D1M(dis)	24.39	26.70	26.12
D1M(con)	27.36	26.29	25.49

^{4}He

E(D1S)= 30.28 MeV

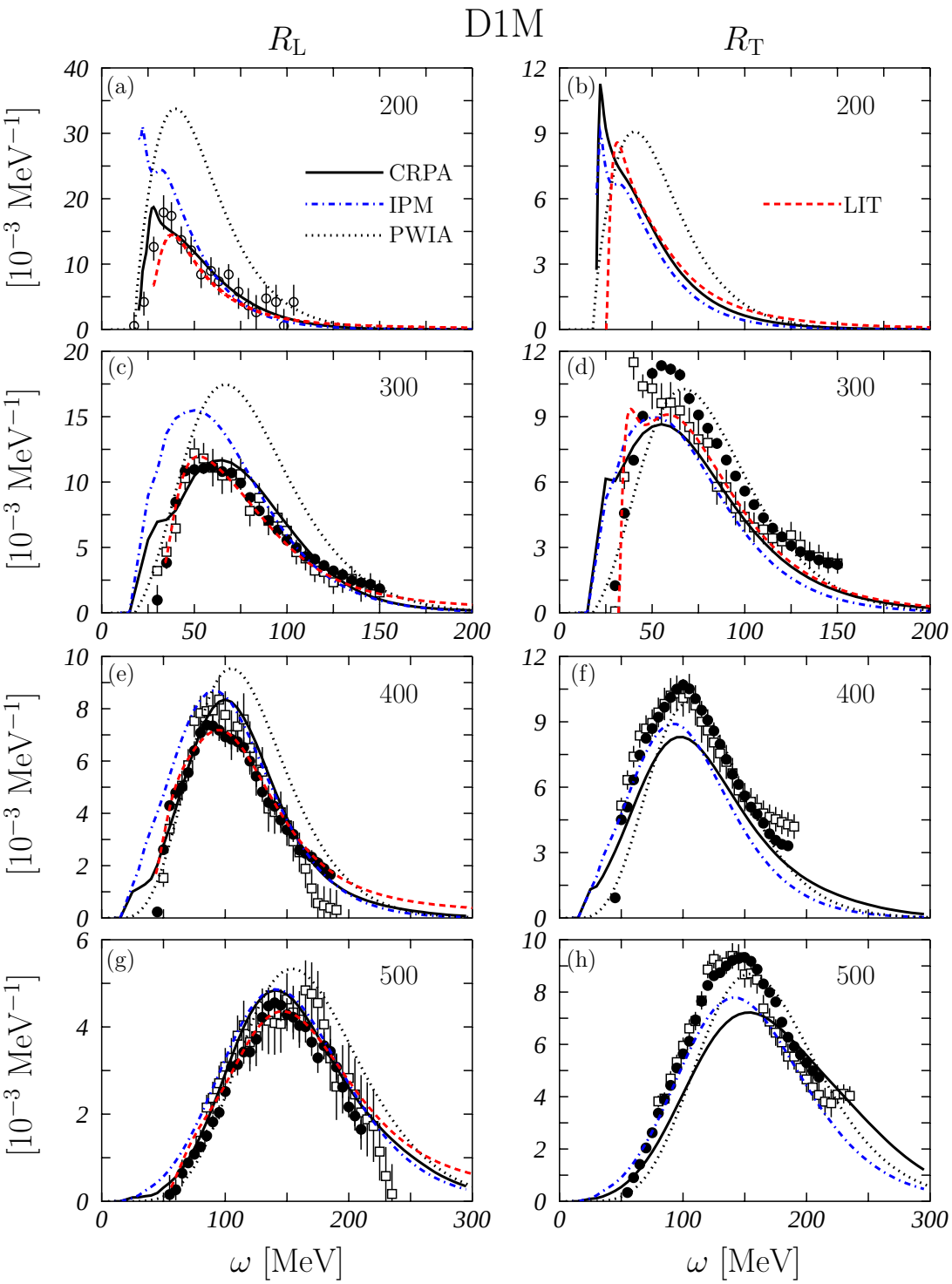
E(D1M)= 29.54 MeV



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 at al., Phys. Rev. Lett. 96 (2006) 112301, G. Orlandini, priv. comm.


D1M
$R_{\rm L}$
$R_{\rm T}$
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
200
300
400
500
CRPA
IPM
PWIA
LIT
$[10^{-3}\ {\rm MeV}^{-1}]$
ω [MeV]