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Effective tensor forces and neutron rich nuclei

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Our calculations

1. Hartree Fock (HF)
2. Random Phase Approximation (RPA)
3. Finite-range interactions
4. Tensor terms

Tensor terms

1. Are they important in effective theories?
2. Does their relevance increases in nuclei with large neutron number?

We consider only the tensor-isospin channel

$$S_{12}(\mathbf{r})\boldsymbol{\tau}(1)\cdot\boldsymbol{\tau}(2)$$

$$S_{12}(\mathbf{r}) = 3\frac{[\boldsymbol{\sigma}(1)\cdot\mathbf{r}]\,[\boldsymbol{\sigma}(2)\cdot\mathbf{r}]}{r^2} - \boldsymbol{\sigma}(1)\cdot\boldsymbol{\sigma}(2)$$

Interactions

taken from the literature
D1S (1)
D1M (2)
GT2 (3)

of our construction
D1SV8 = D1S + tensor + modified spin-orbit
D1MV8 = D1M + tensor + modified spin-orbit
GT2* = GT2 - tensor term

(1) J.F. Berger, M.Girod, D.Gogny, Comp. Phys. Comm. 63 (1991) 365.

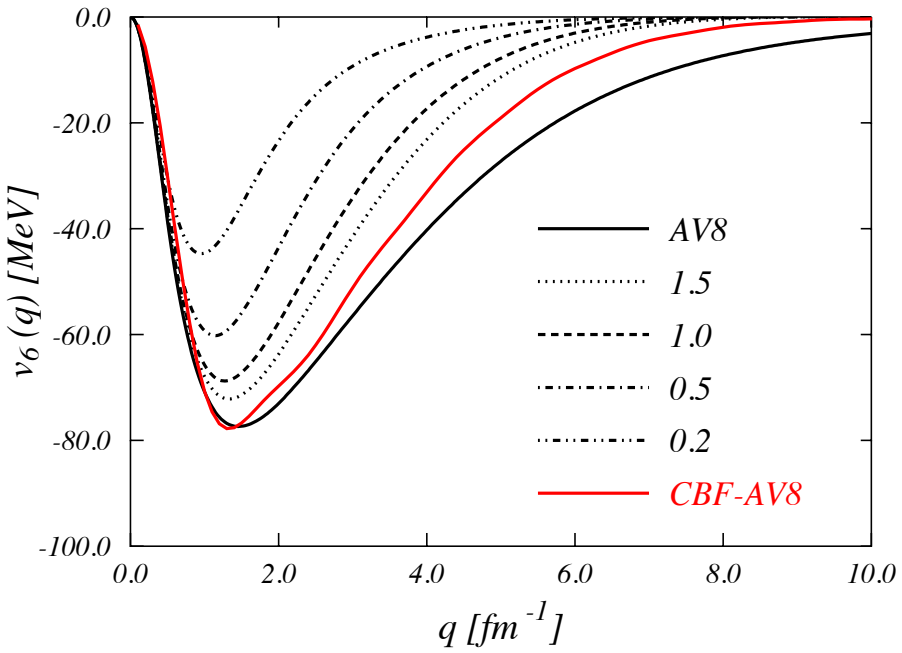
(2) S. Goriely, M. Girod, S. Hilaire, S. Péru, Phys. Rev. Lett. 102 (2009) 252501.

(3) T. Otsuka, T. Matsuo, D. Abe, Phys. Rev. Lett. 97 (2006) 162501.

Tensor term in the isospin channel

$$v_b^{t\tau}(r) = v_{AV8'}^{t\tau}(r)(1 - e^{-br^2})$$

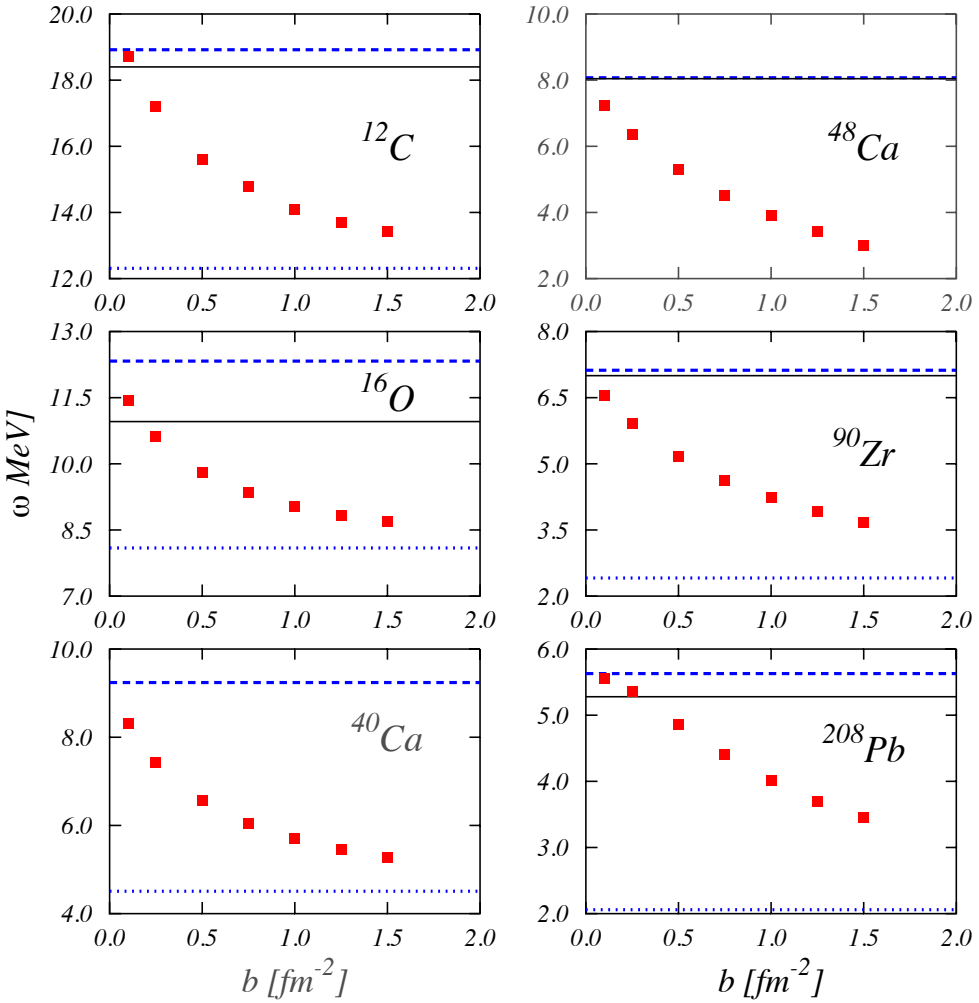
$$v_6(q)\, S_{12}(\mathbf{q}) = \int d^3r\, e^{i\mathbf{q}\cdot\mathbf{r}}\, v^{t\tau}(r)\, S_{12}(\mathbf{r}) = -4\pi \int dr\, r^2\, j_2(qr)\, v^{t\tau}(r) S_{12}(\mathbf{r})$$



CBF correlation from

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

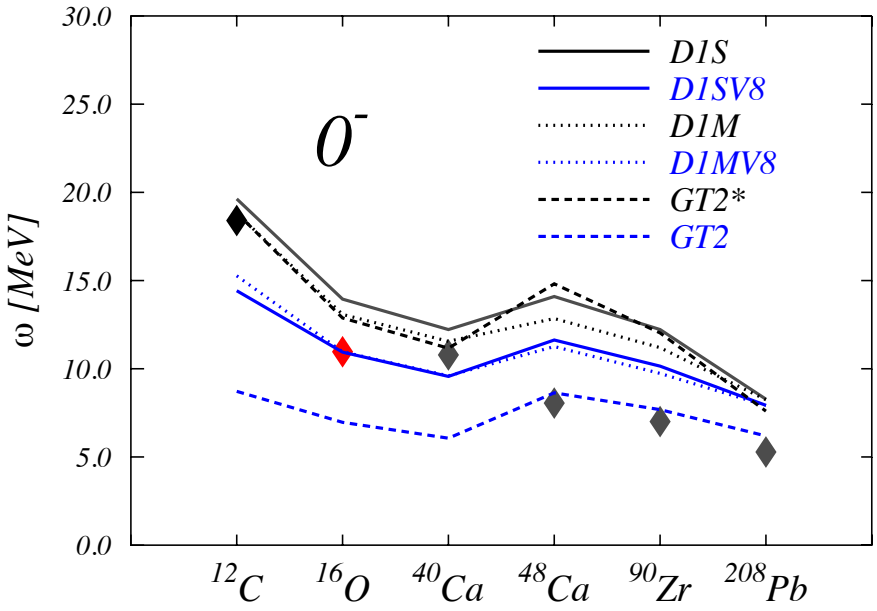
Energies of the first 0^- states

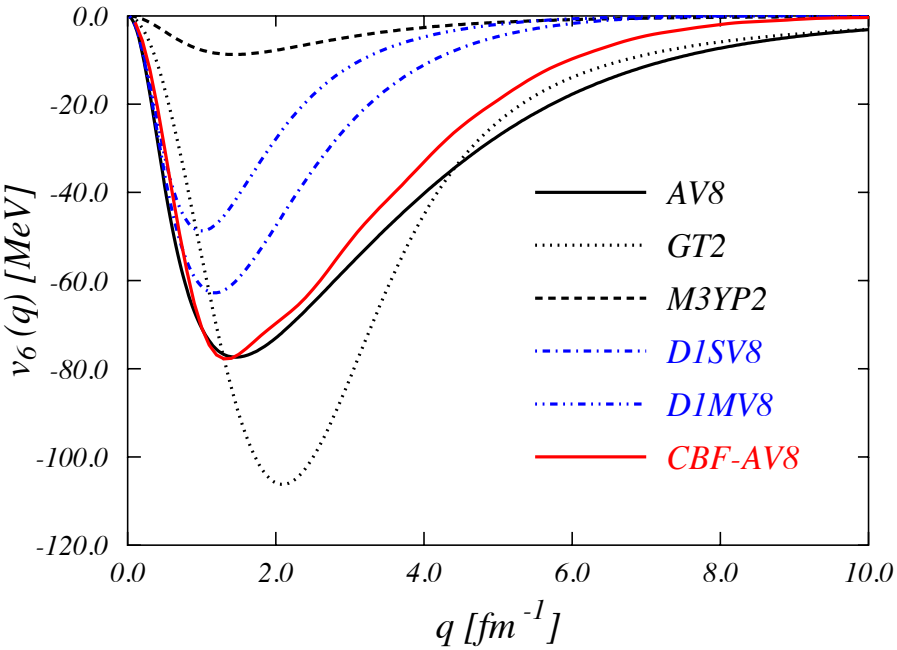


Phenomenological RPA calculations with LM + Tensor term

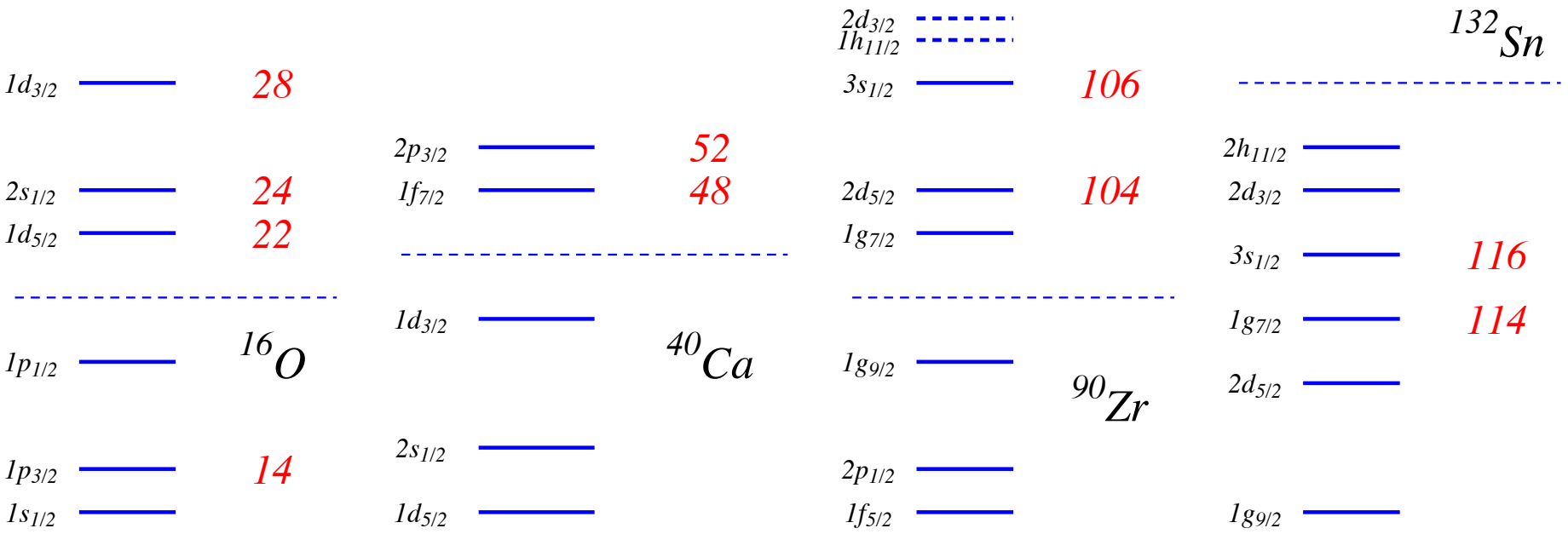
- *LM*
- *LM+AV8*
- *exp*

Iterative procedure

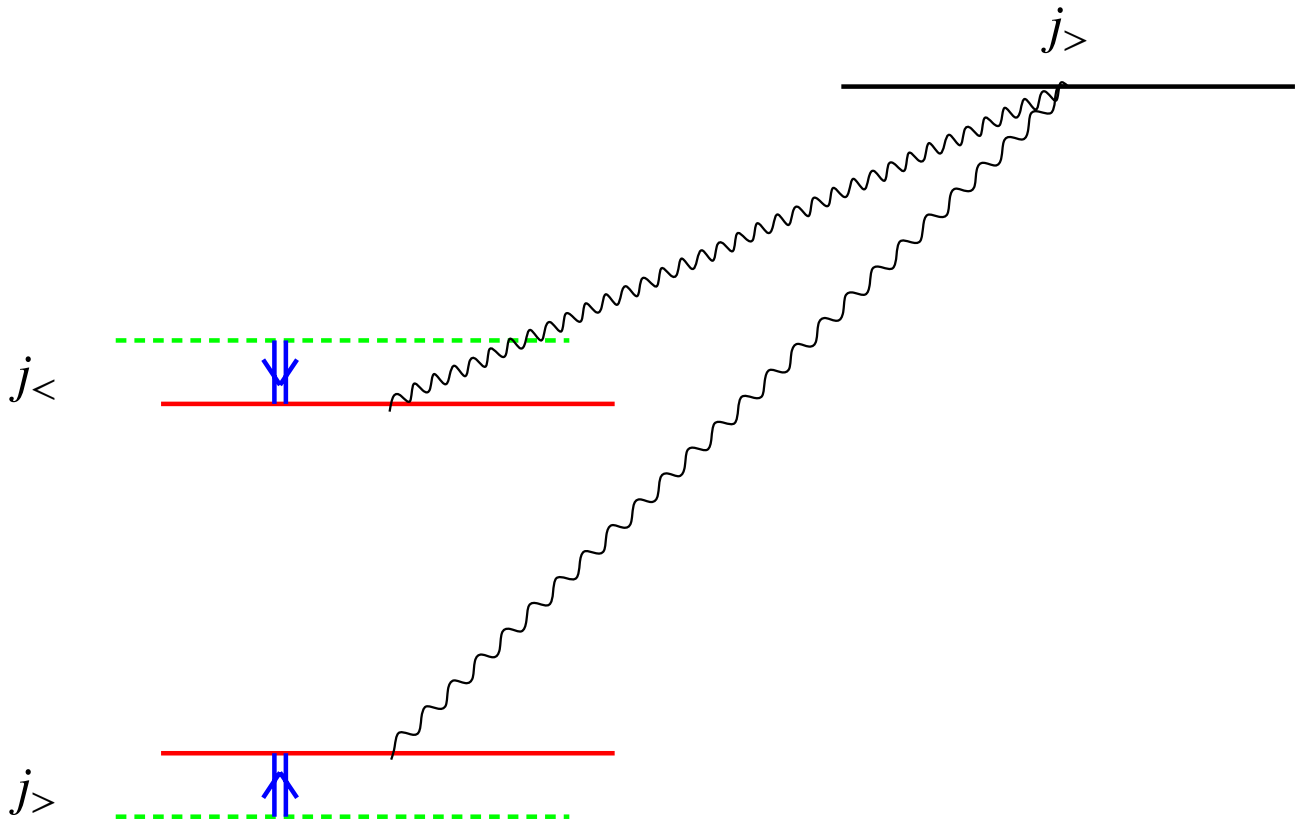




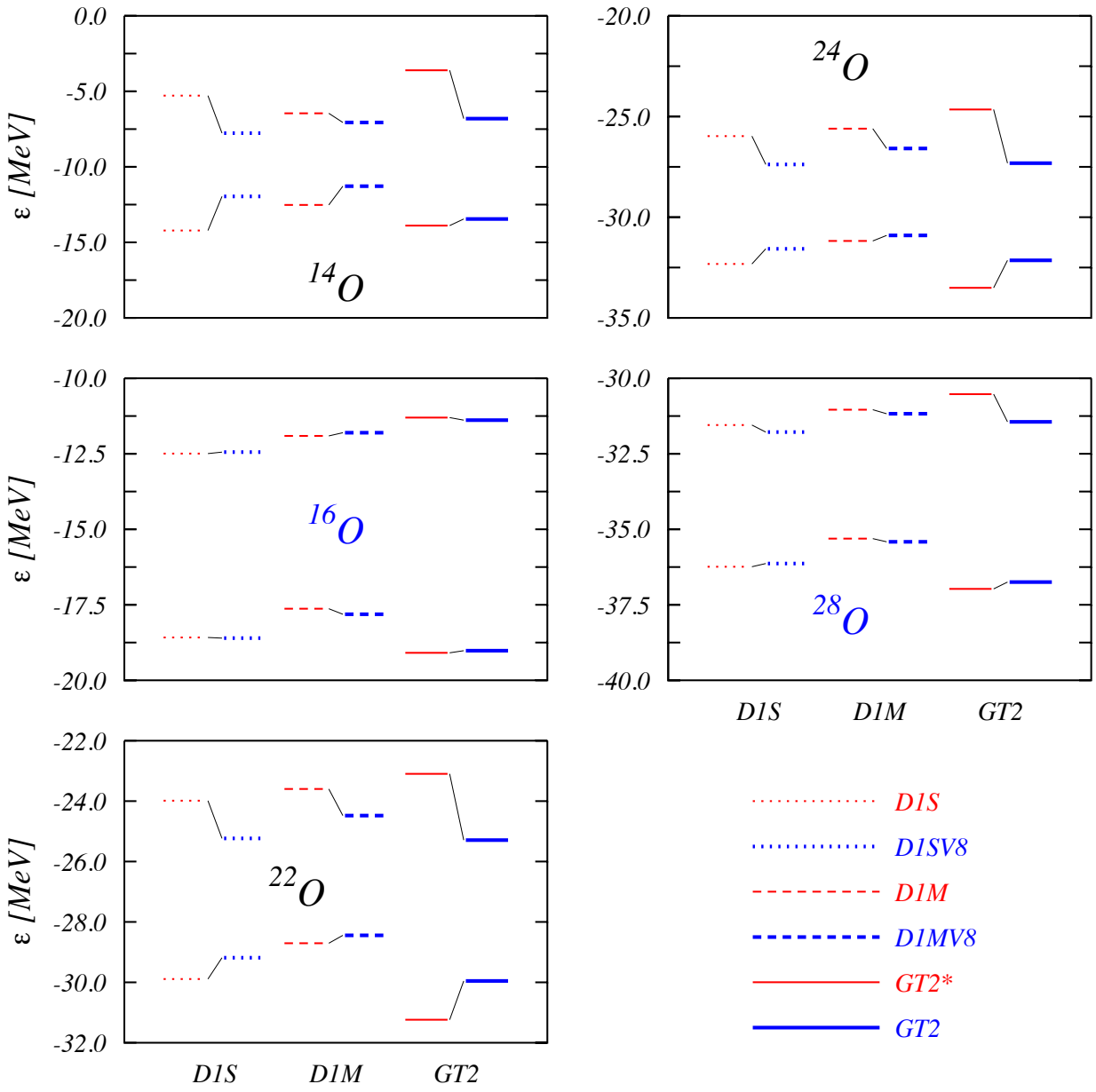
M3YP2 from: H. Nakada, Phys. Rev. C 68 (2003) 014316


1d3/2
28
2s1/2
24
1d5/2
22
1p1/2
16O
1p3/2
14
1s1/2
2p3/2
52
1f7/2
48
1d3/2
40Ca
2s1/2
1d5/2
2d3/2
1h11/2
3s1/2
106
2d5/2
104
1g7/2
1g9/2
90Zr
2p1/2
1f5/2
132Sn
2h11/2
2d3/2
3s1/2
116
1g7/2
114
2d5/2
1g9/2

Otsuka's tensor effect

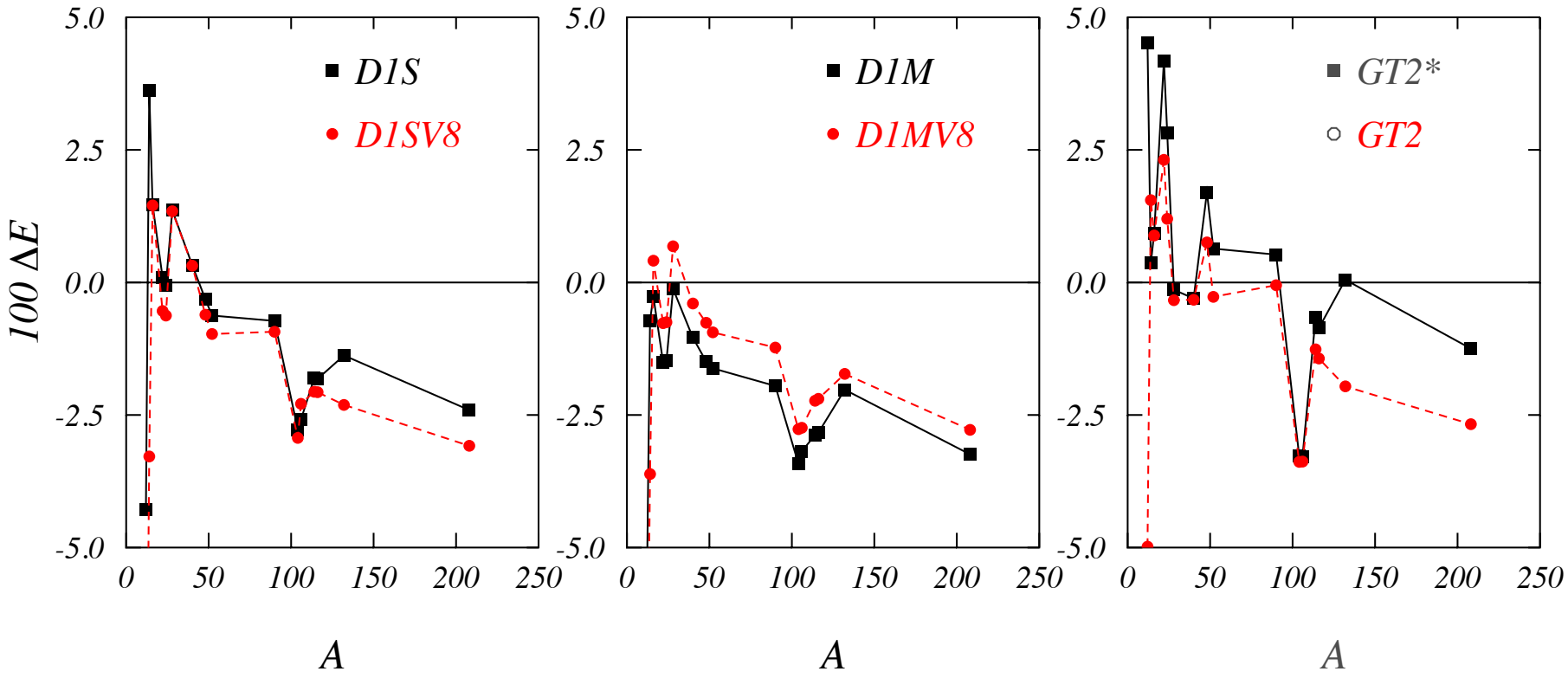


T. Otsuka et al. PRL 95 (2005) 232502

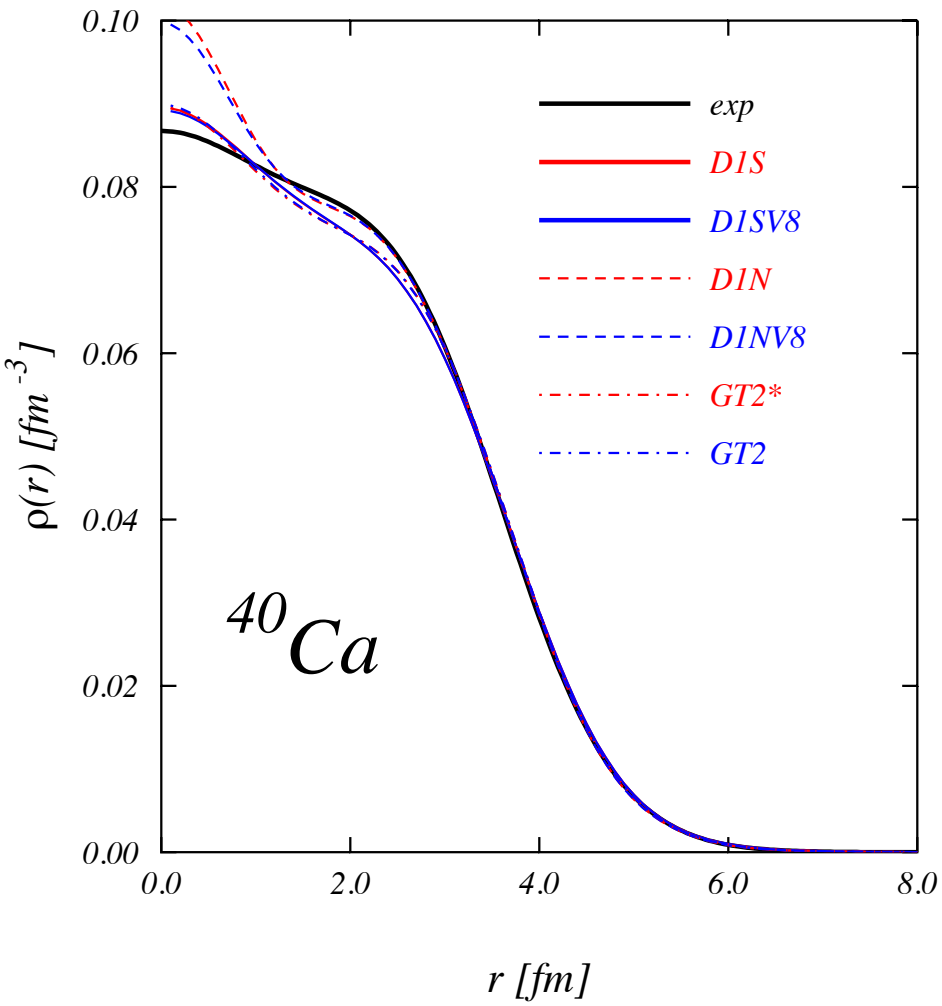


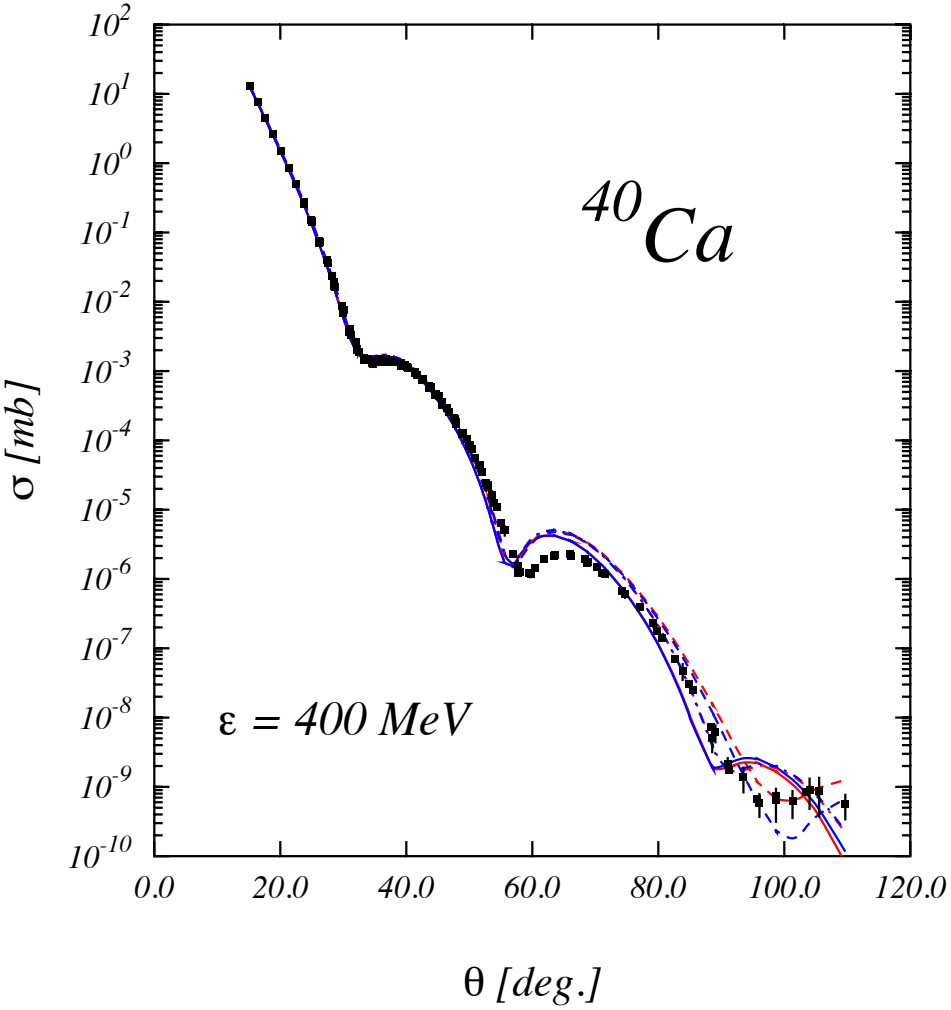
$1p_{1/2}$, $1p_{3/2}$ proton states

Binding energies



$$\Delta E = \frac{E^{th} - E^{exp}}{E^{exp}}$$

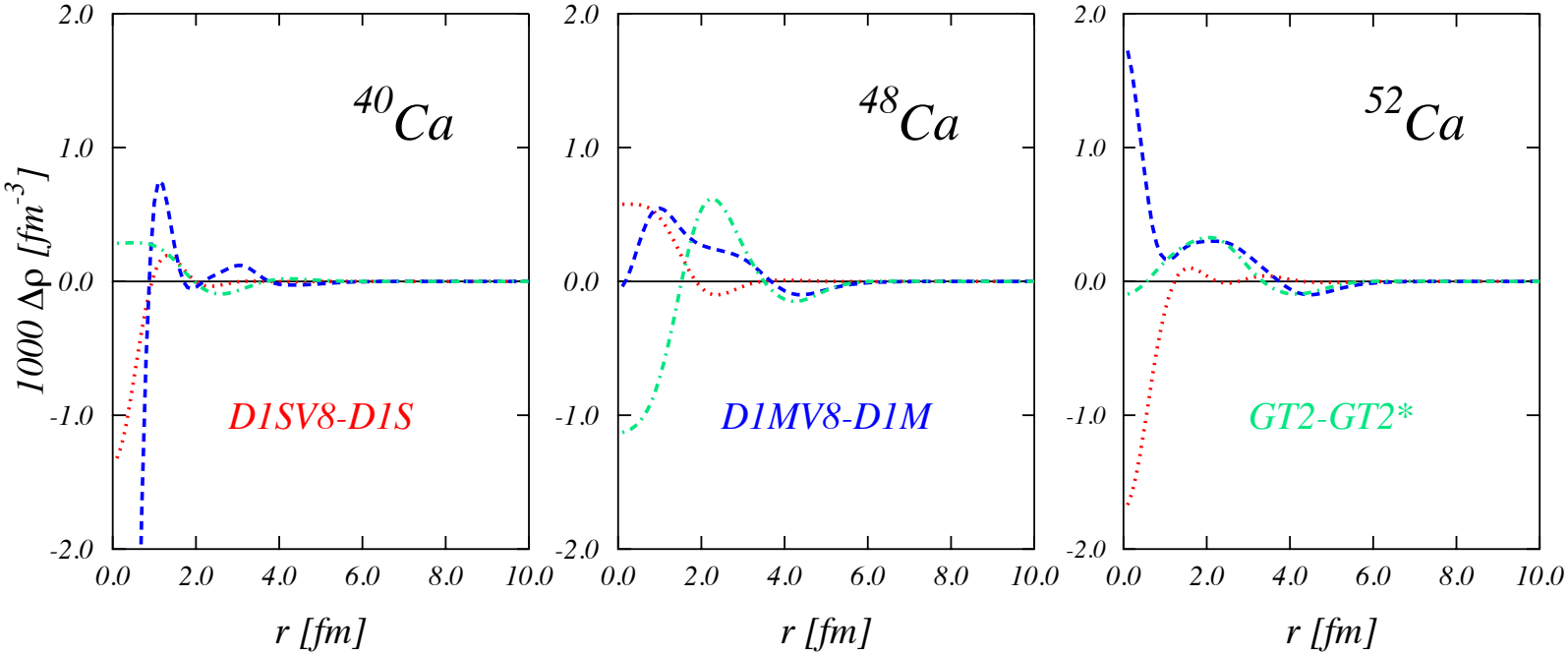




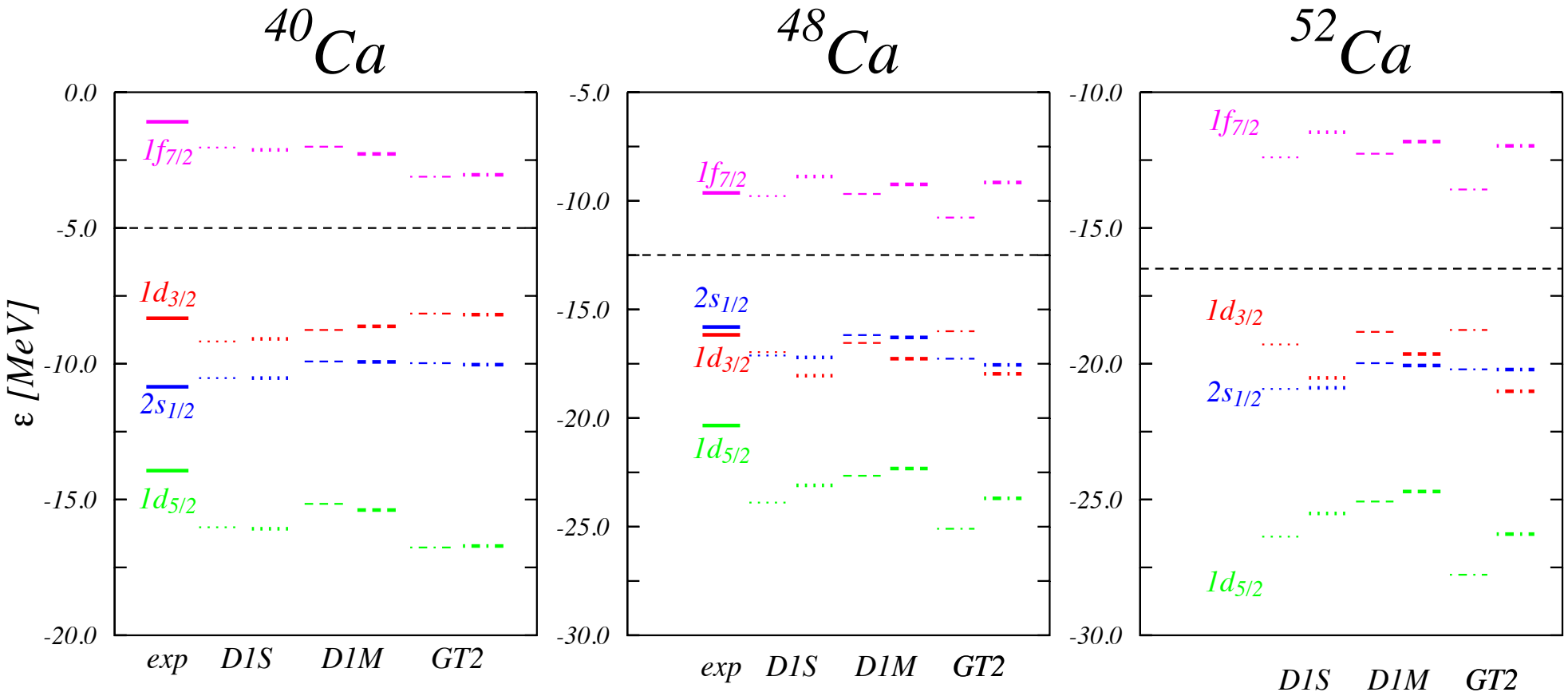
Cross section data from

J. Cavedon, Ph.D. thesis, Universitè de Paris-sud, Paris (1980).

Protons

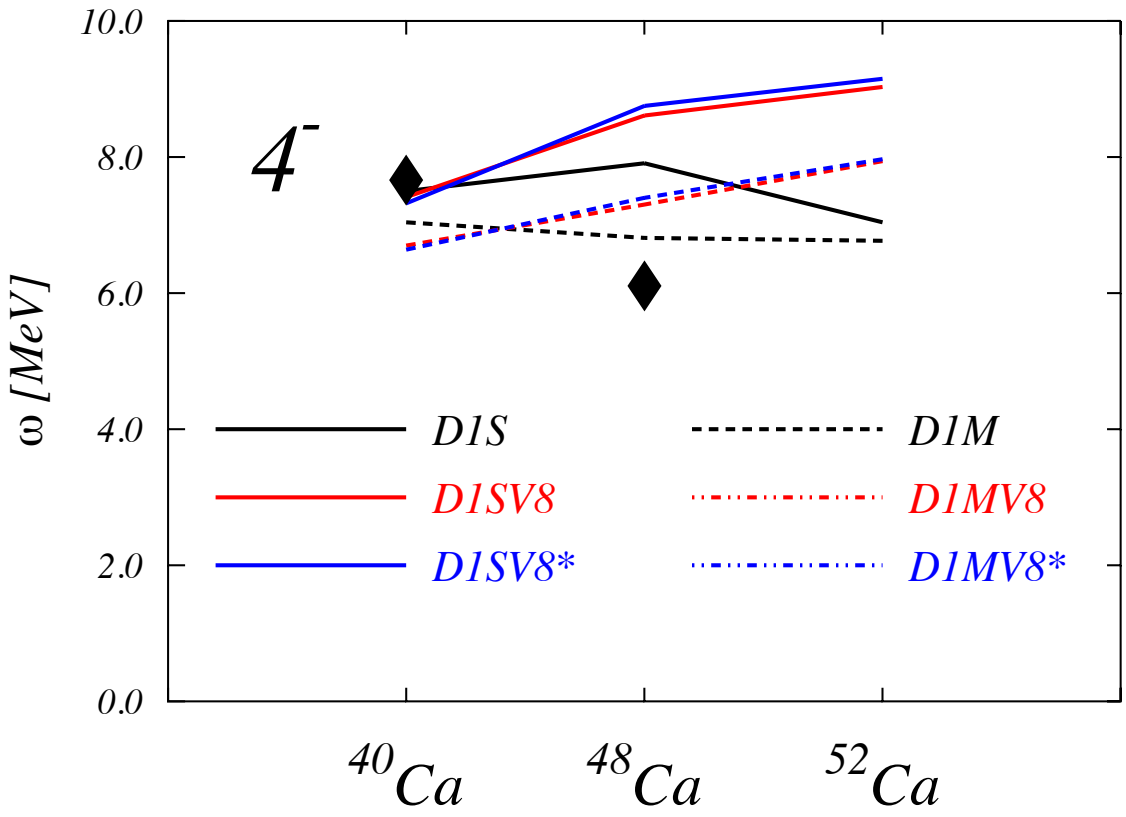


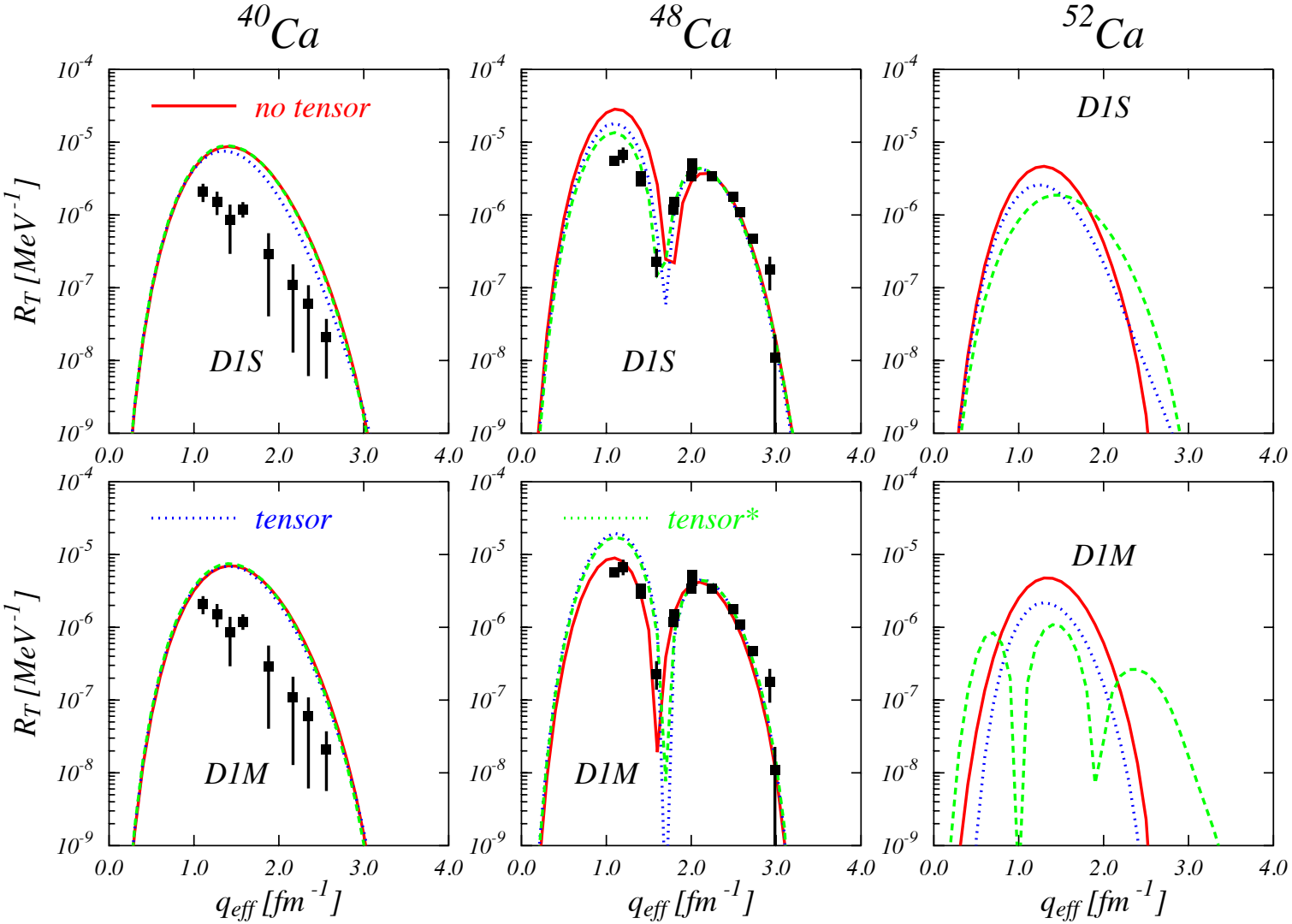
$$\Delta\rho(r) = \rho^{with\ tensor}(r) - \rho^{no\ tensor}(r)$$



Experimental energies from (d,^{3}He) reactions

P. Doll, G.J. Wagner, K.T. Knöpfle, G. Mairle, Nucl. Phys. A 263 (1976) 210.


10.0
8.0
6.0
4.0
2.0
0.0
ω [MeV]
4⁻
D1S
D1M
D1SV8
D1MV8
D1SV8*
D1MV8*
40Ca
48Ca
52Ca



^{40}Ca data: C. F. Williamson et al., (1980) unpublished

^{48}Ca data: J. Wise et al., Phys. Rev. C 31 (1985) 1699

Conclusions

Otsuka's effect confirmed (theory)
Reliable predictions from Mean-Field calculations
Interplay between tensor effects in HF and RPA
Tensor effects relatively small on global nuclear properties
Tensor effects increase with increasing neutron number

Tensor to be included !!