Systematics of strength functions of isoscalar dipole and monopole modes

J. Terasaki (Univ. of North Carolina at Chapel Hill)

- Quasiparticle random-phase approximation
- Systematics of strength functions: IS 1^- Ni and 0^+ Sn
- Incompressibility of nuclear matter

July. 14, 2005, Notre Dame

Quasiparticle random phase approximation (QRPA)

What approximation?

1. Excitations are represented by linear combinations of 2-quasiparticle creation and annihilations (if there is no pairing correlations, 1p-1h creation and annihilation).

2. Good for collective vibrations (the more harmonic, the better).

Scheme of solution

HFB ← Dobaczewski et al. Nucl. Phys. A422 (1984) 103
q.p. wave functions are obtained.

QRPA ← matrix formulation
Cf. e.g. D.J. Rowe, Nuclear Collective Motion

HFB

↓ ← self-consistent mean field and pair field
w.f. of canonical basis, uv factors
two-body interaction

QRPA

Self-consistent
Spherical symmetry
J.T. et al., P.R.C 71, 034310 (2005)

Interaction used

Skyrme interaction for particle-hole matrix elements

SkM*, SLy4, SkP, SkO’

For particle-particle and hole-hole matrix elements

Volume-type pairing interaction
(no density dependence)

Definitions of the transition operators used ($J^{\pi}=0^{+}$, IS)

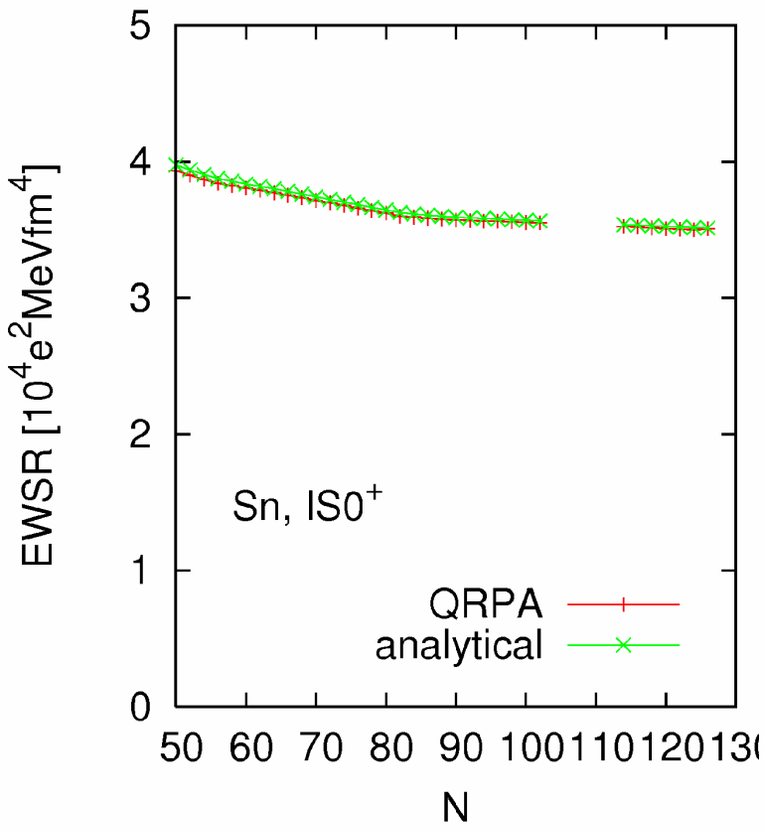
$$F_{00}^{IS} = \frac{eZ}{A} \sum_{i=1}^{A} r_i^2$$

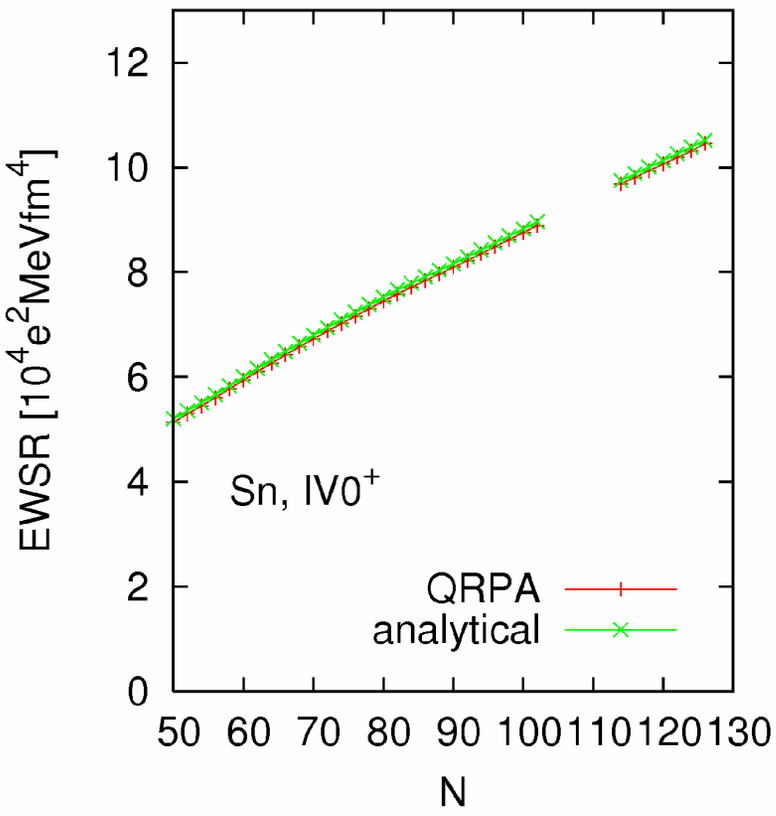
used by G.F. Bertsch, S. Kamerdzhiev, S. Sagawa (not recent ones) …

Energy-weighted sum rule (EWSR)

$$\sum_k E_k \left| \langle k | F_{00}^{IS} | 0 \rangle \right|^2 = 2 \frac{e^2 \hbar^2}{m} \frac{Z^2}{A} \langle r^2 \rangle$$

Energy-weighted sum rule, 0^+ (SkM*)





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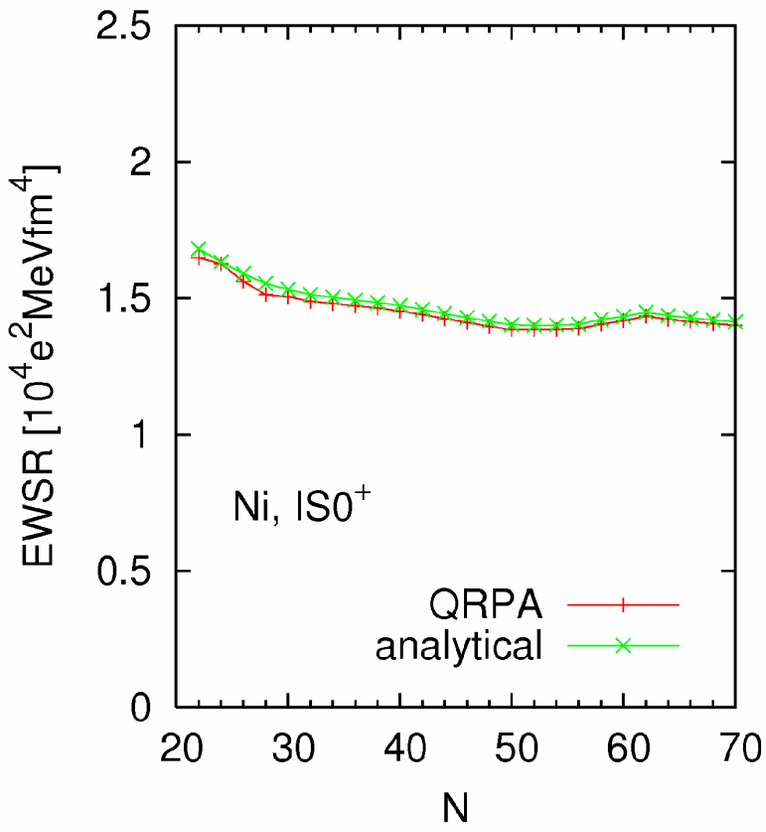

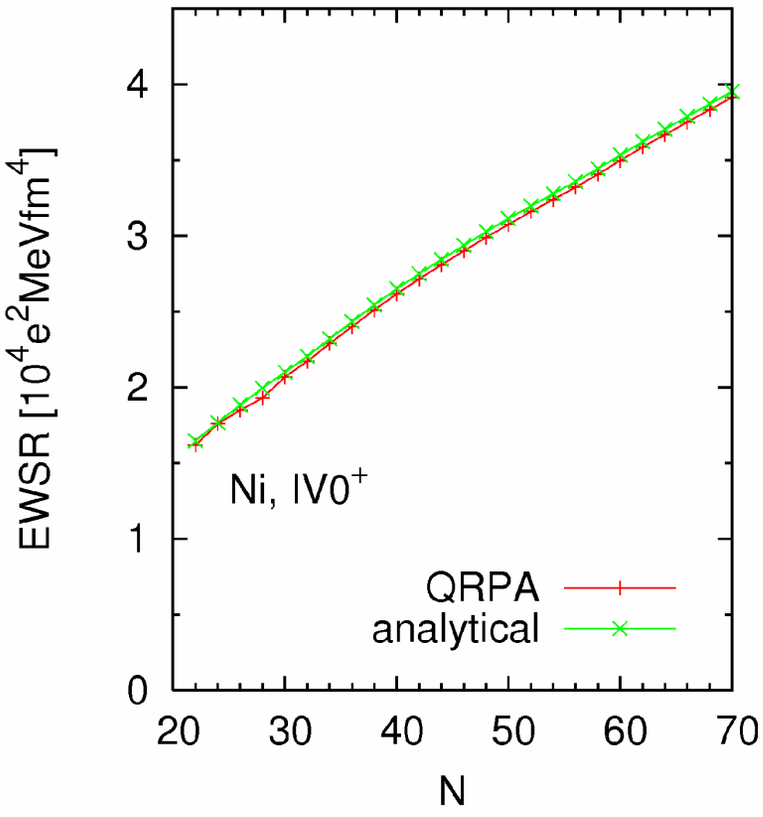

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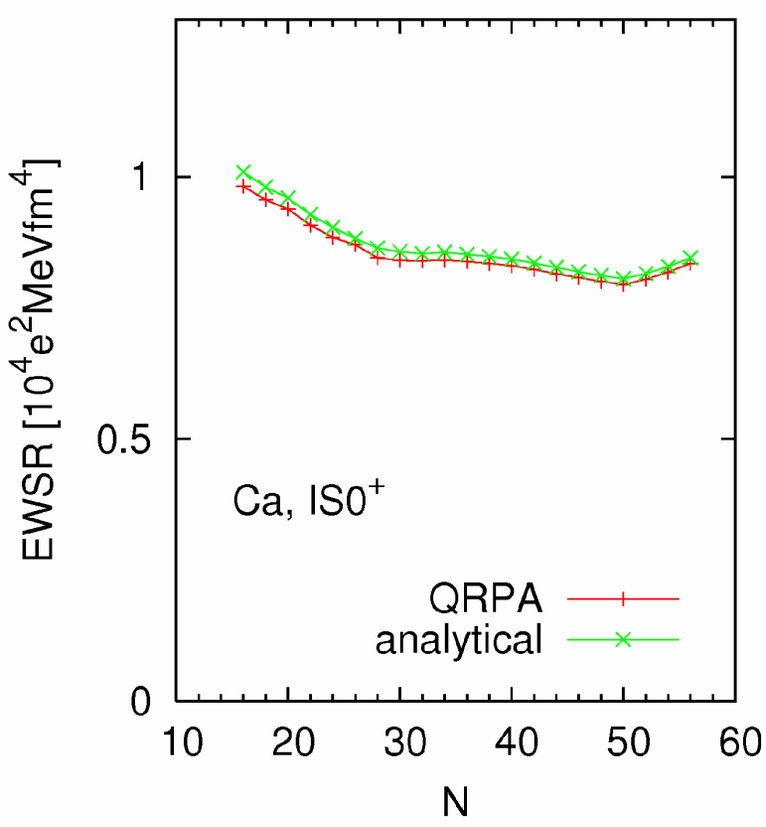
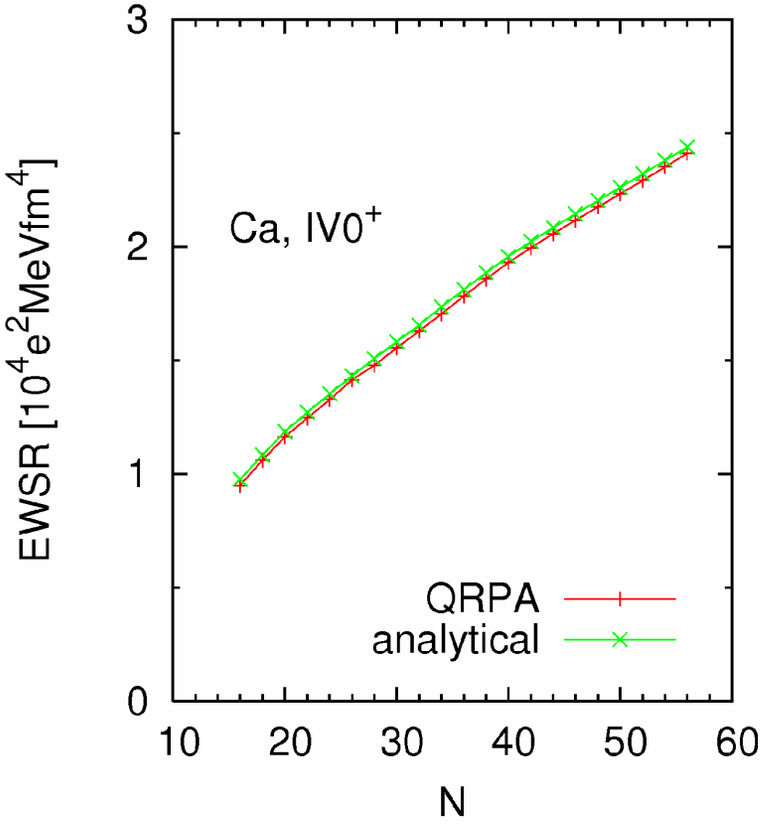
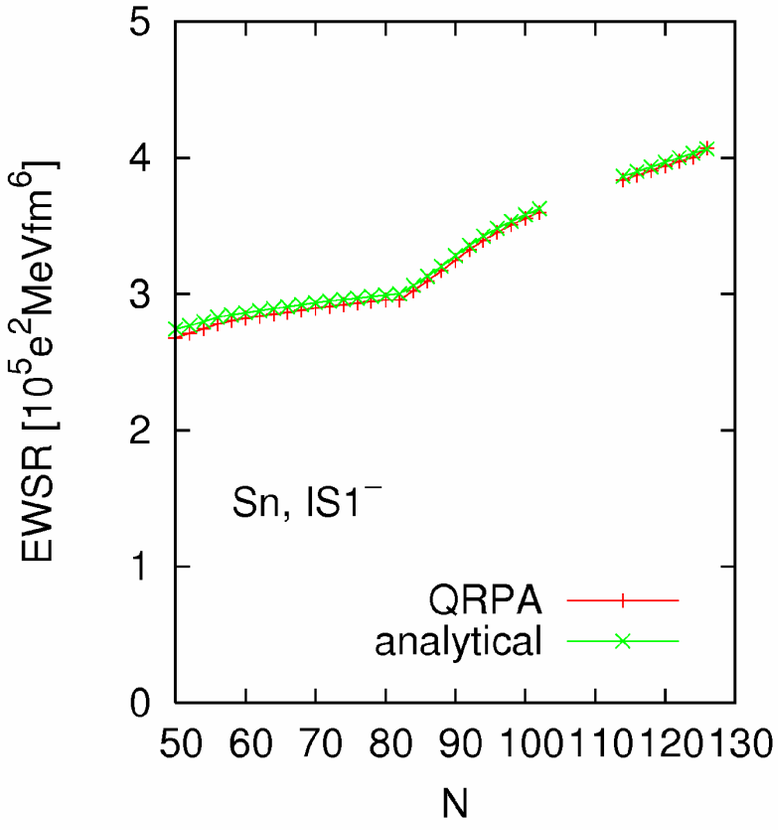
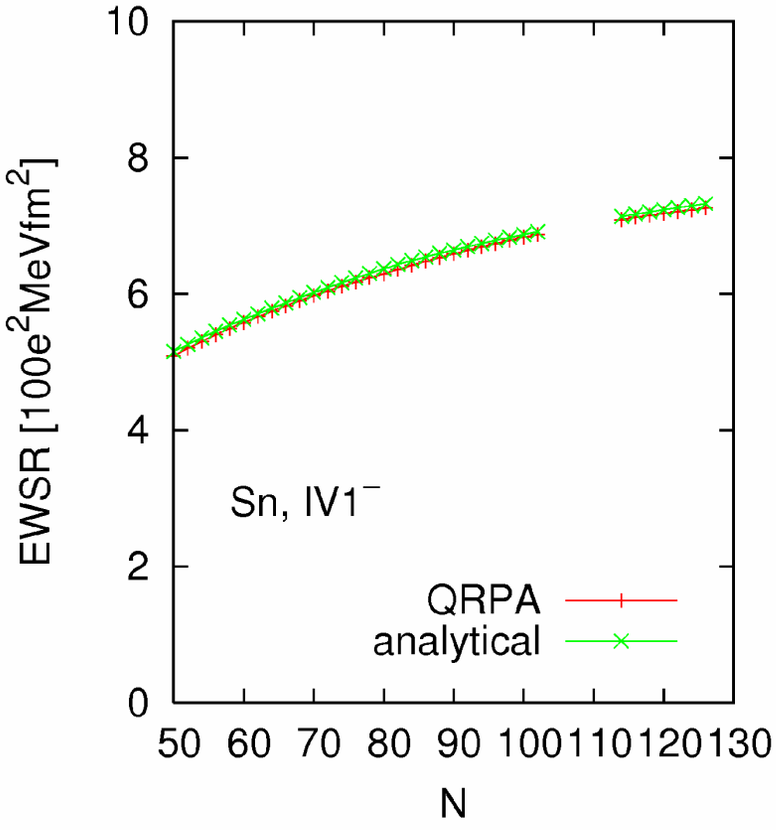


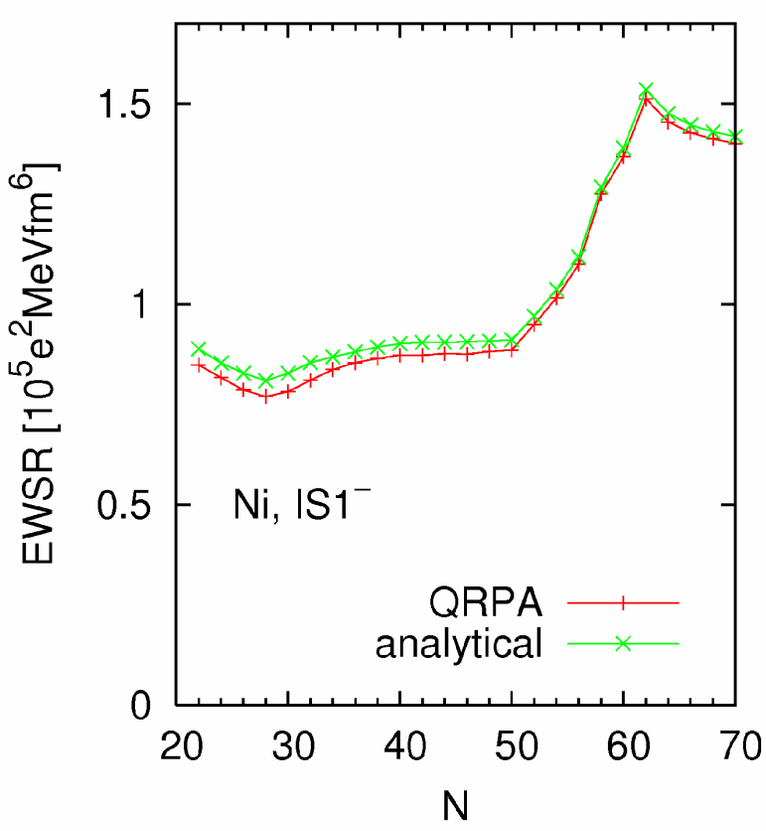


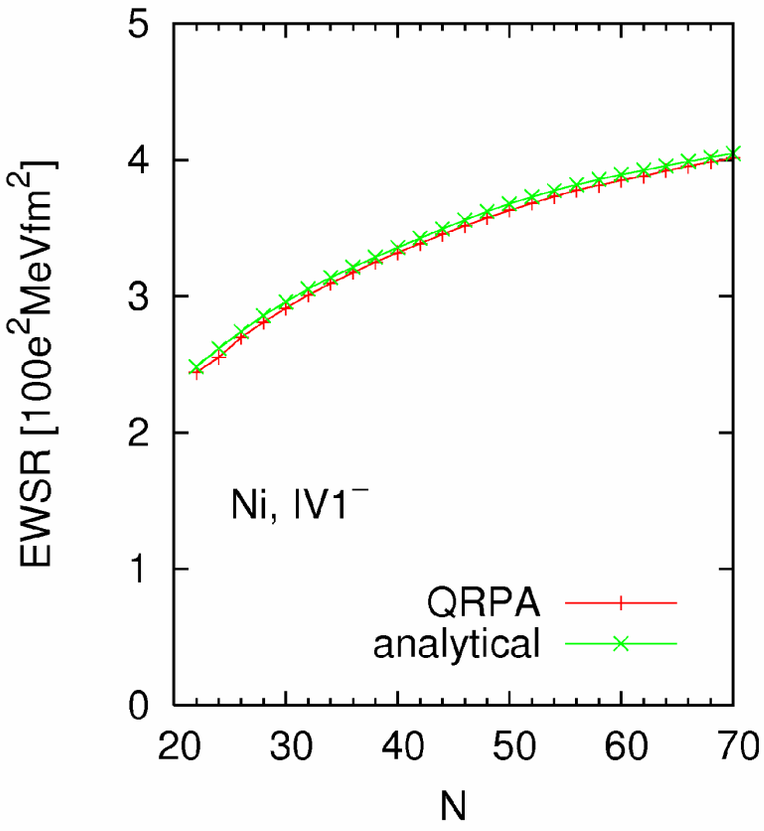
Energy-weighted sum rule, 1^- (SkM*)





Energy-weighted sum rule, 1^- (SkM*)





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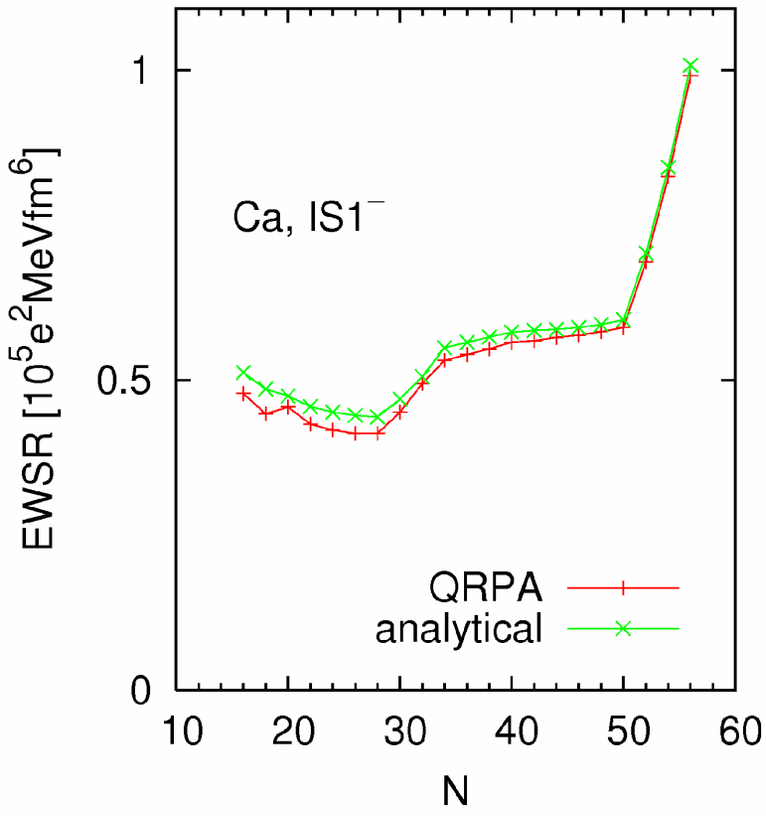
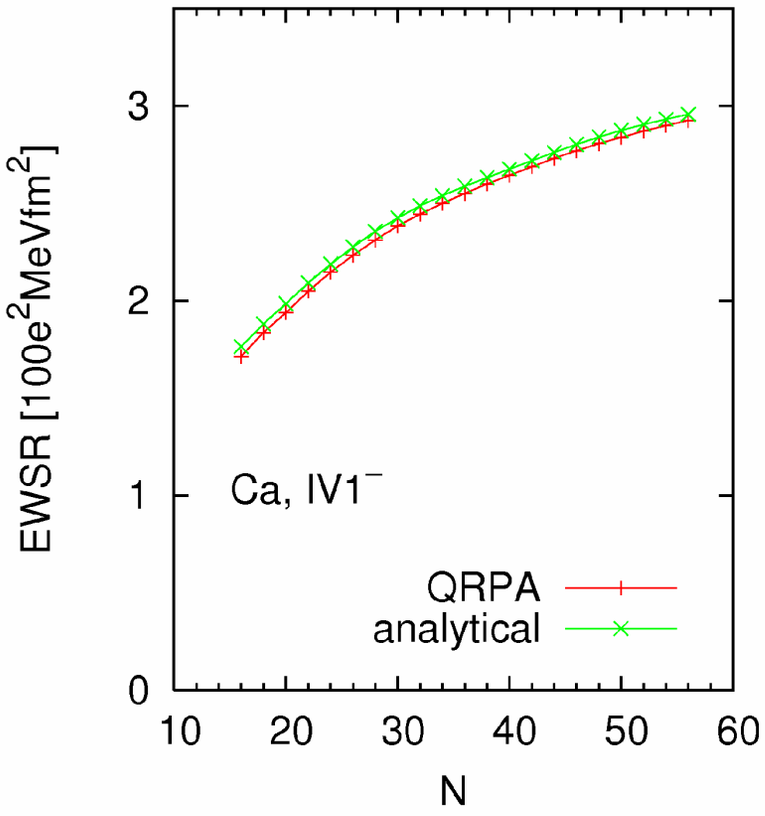
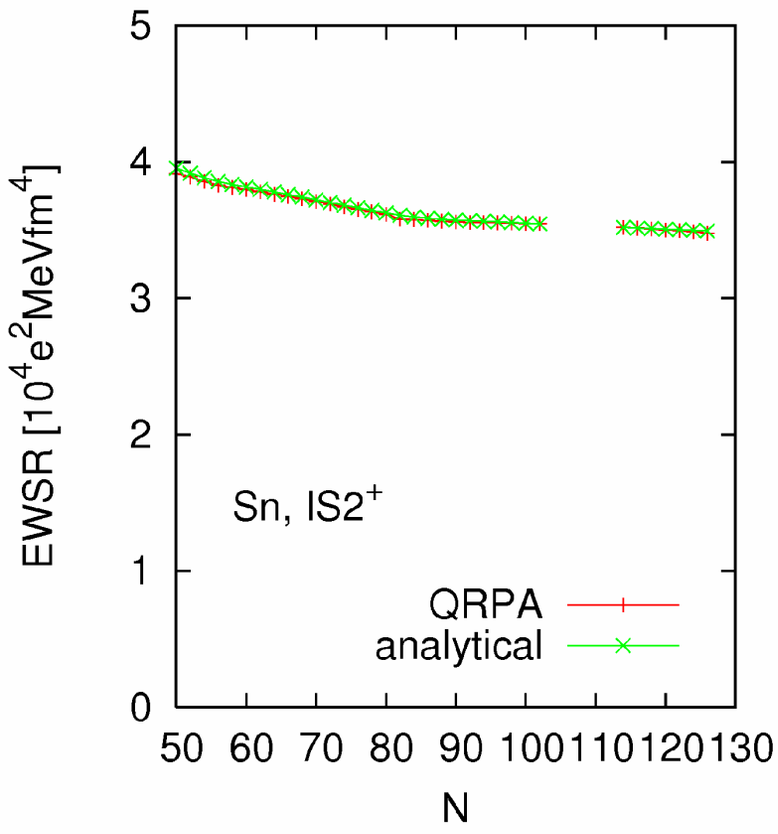
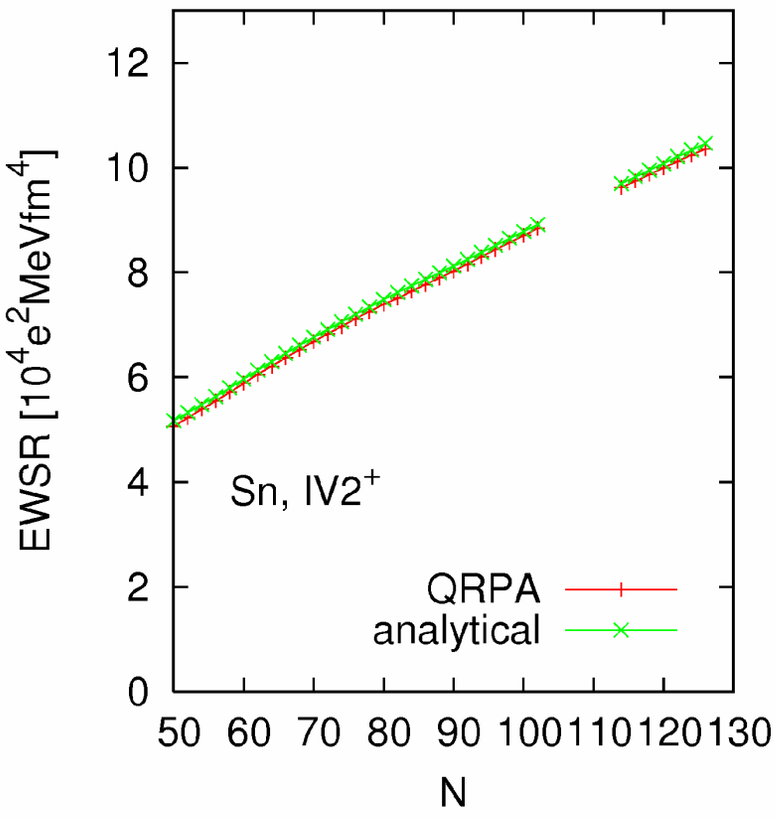




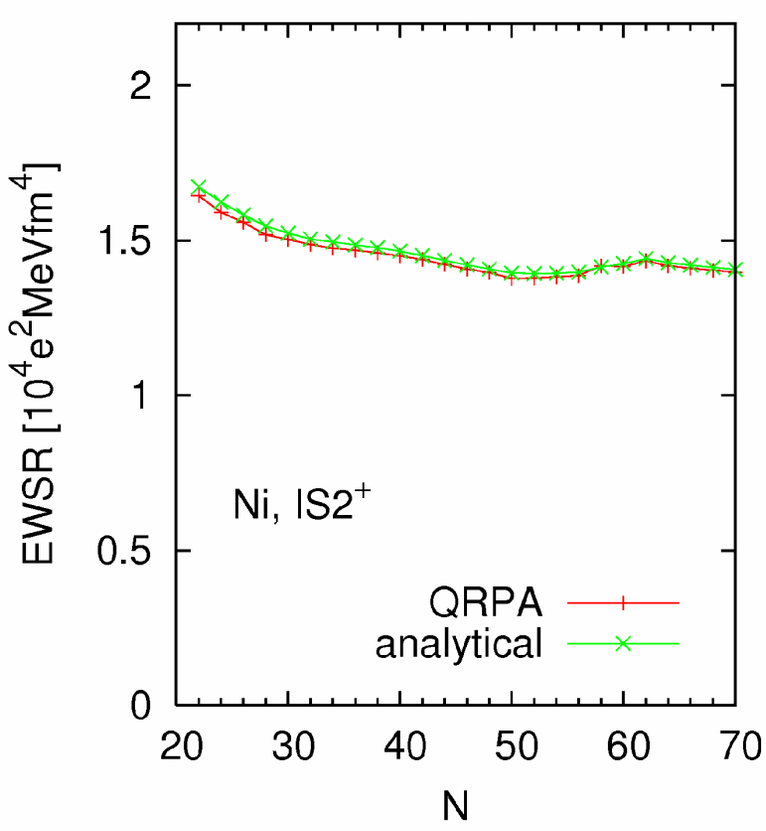
Energy-weighted sum rule, 2^+ (SkM*)

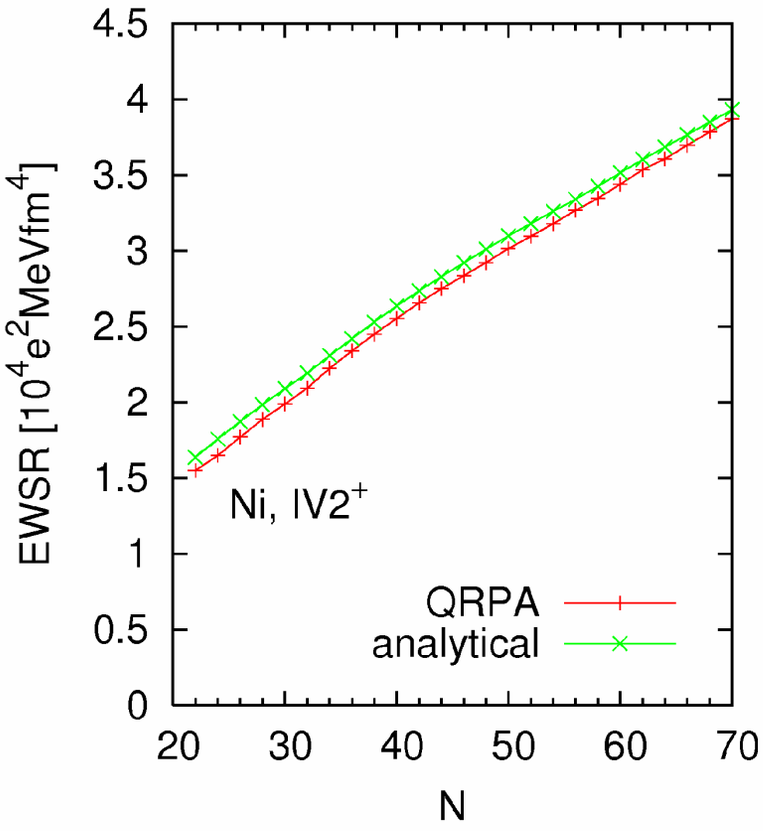




$$\mathrm{EWSR}(\mathbf{0}^+)/\mathrm{EWSR}(\mathbf{2}^+) = \frac{\mathbf{8}\boldsymbol{p}}{\mathbf{25}} \,@\, \mathbf{1}$$

Energy-weighted sum rule, 2^+ (SkM*)





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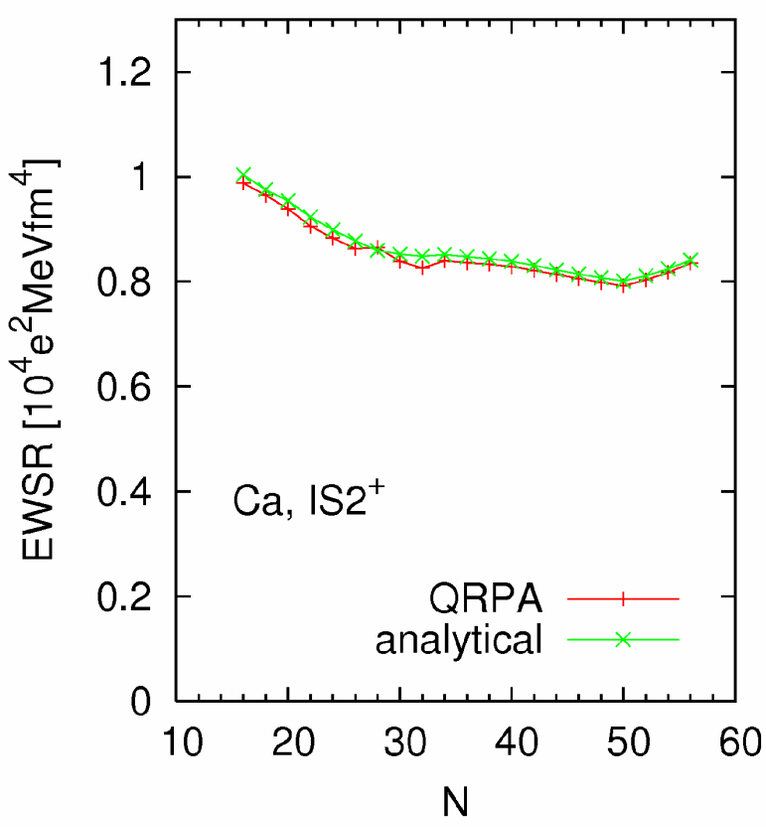
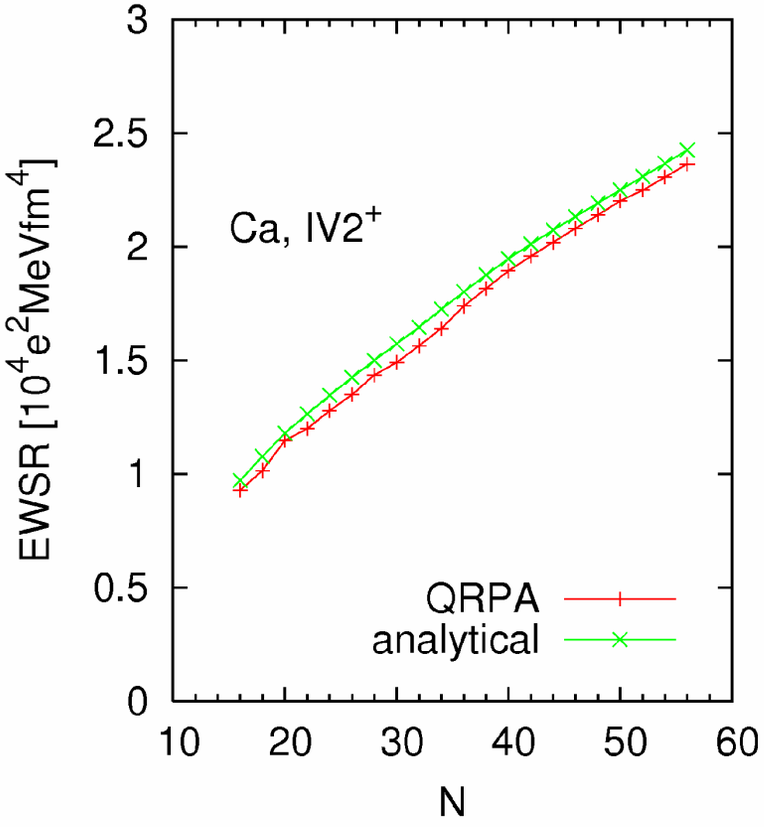
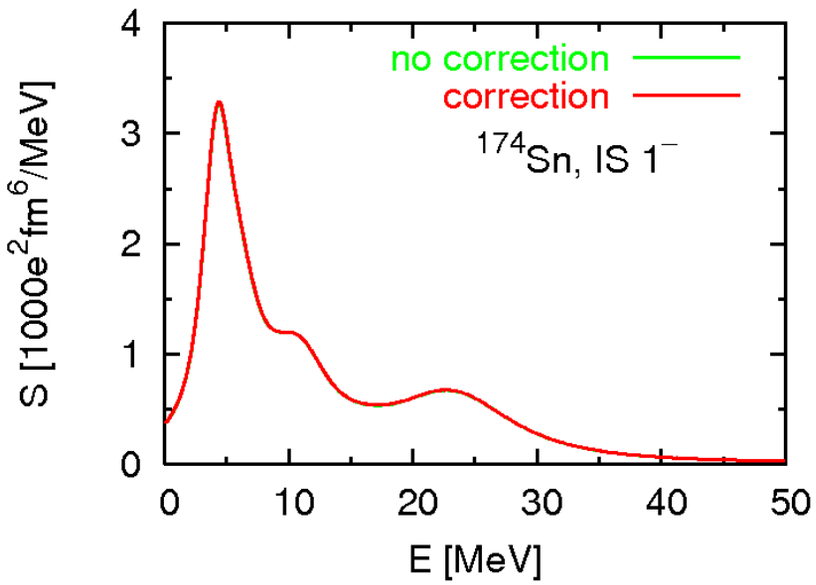
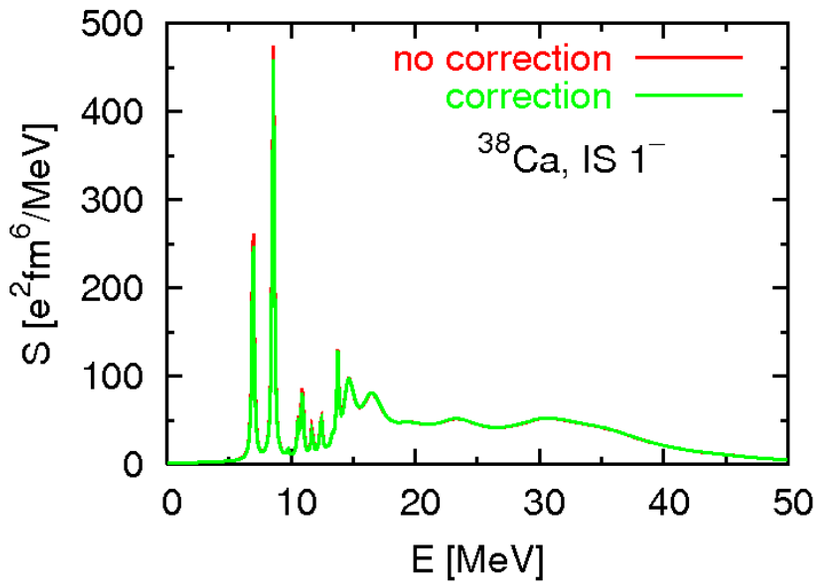




Separation of the spurious component; $J^{\pi} = 1^{-}$ mode



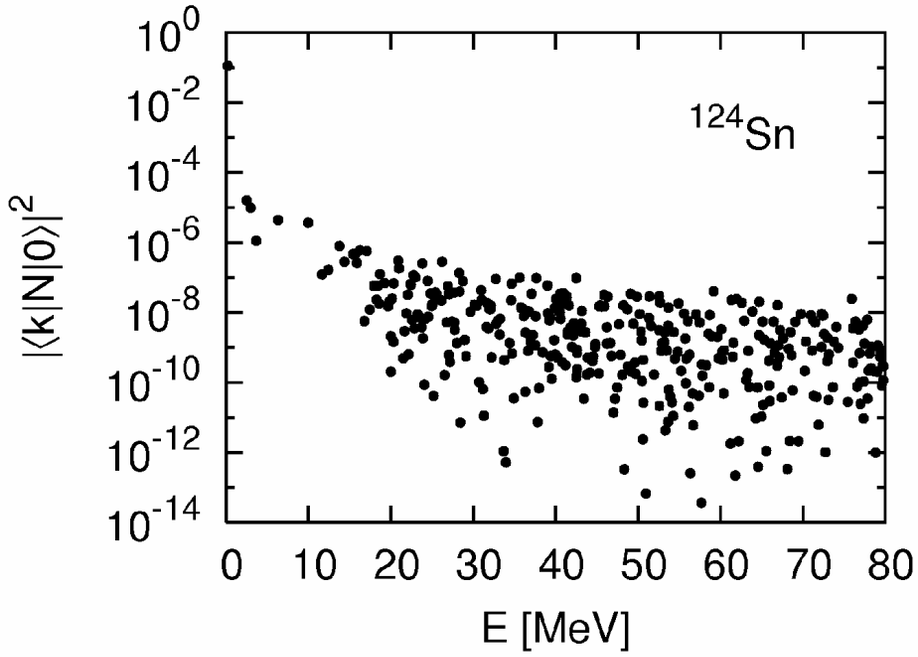


no correction $$F_{1M}(\underline{r}) = r^3 Y_{1M}(O)$$

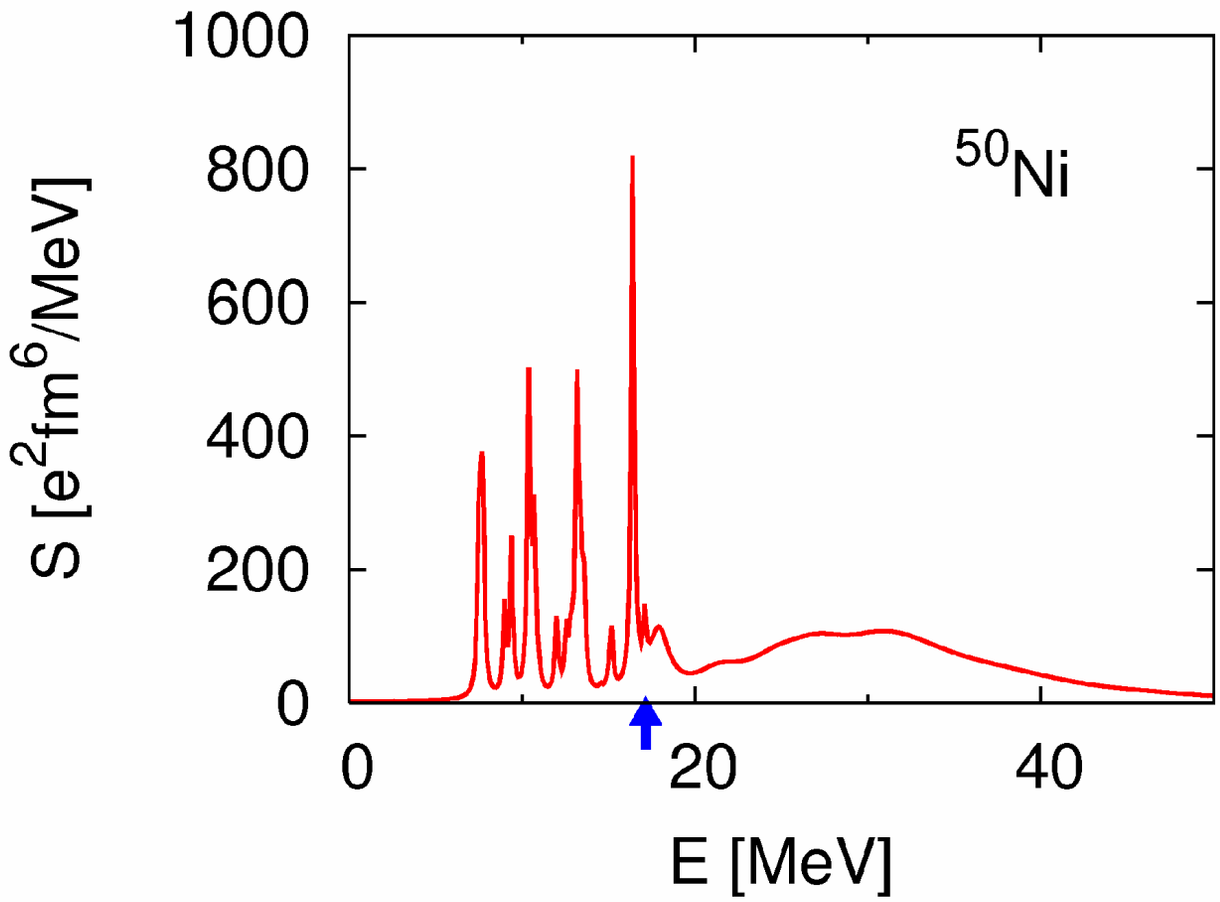
correction $$F_{1M}(\underline{r}) = \left(r^3 - \frac{5}{3}\langle r^2 \rangle r \right) Y_{1M}(O)$$

Separation of the spurious component; $J^{\pi} = 0^{+}$ mode

Strength function for the neutron number operator



Isoscalar 1^- strength functions



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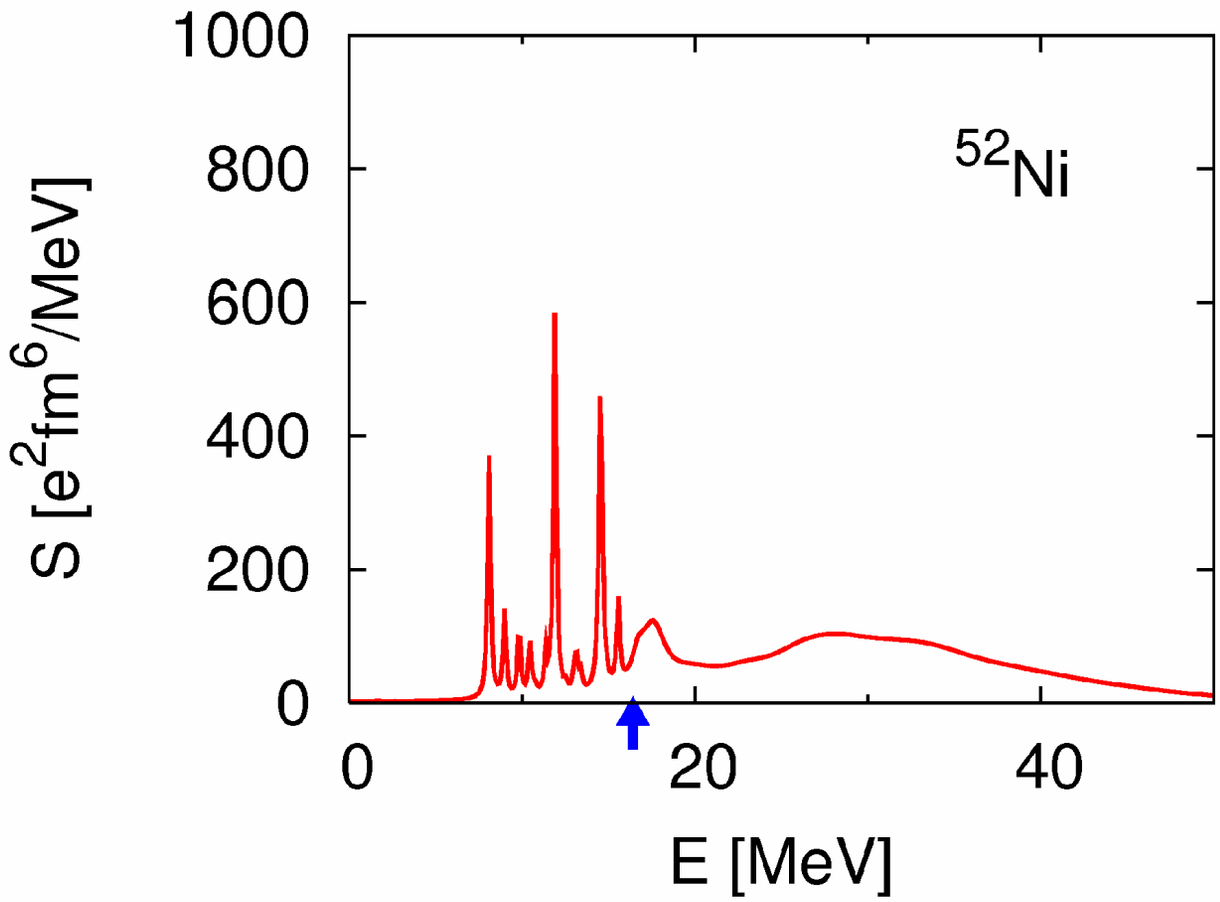

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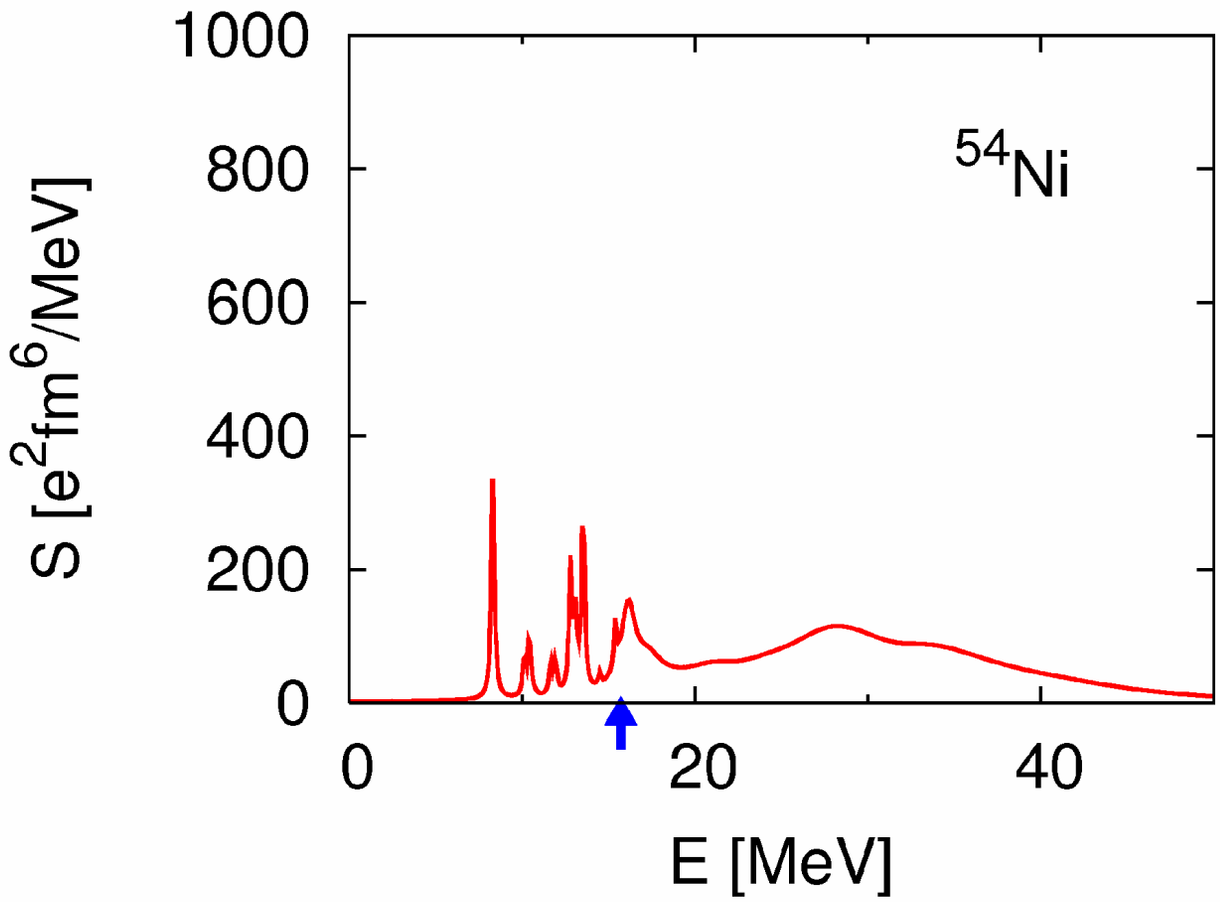

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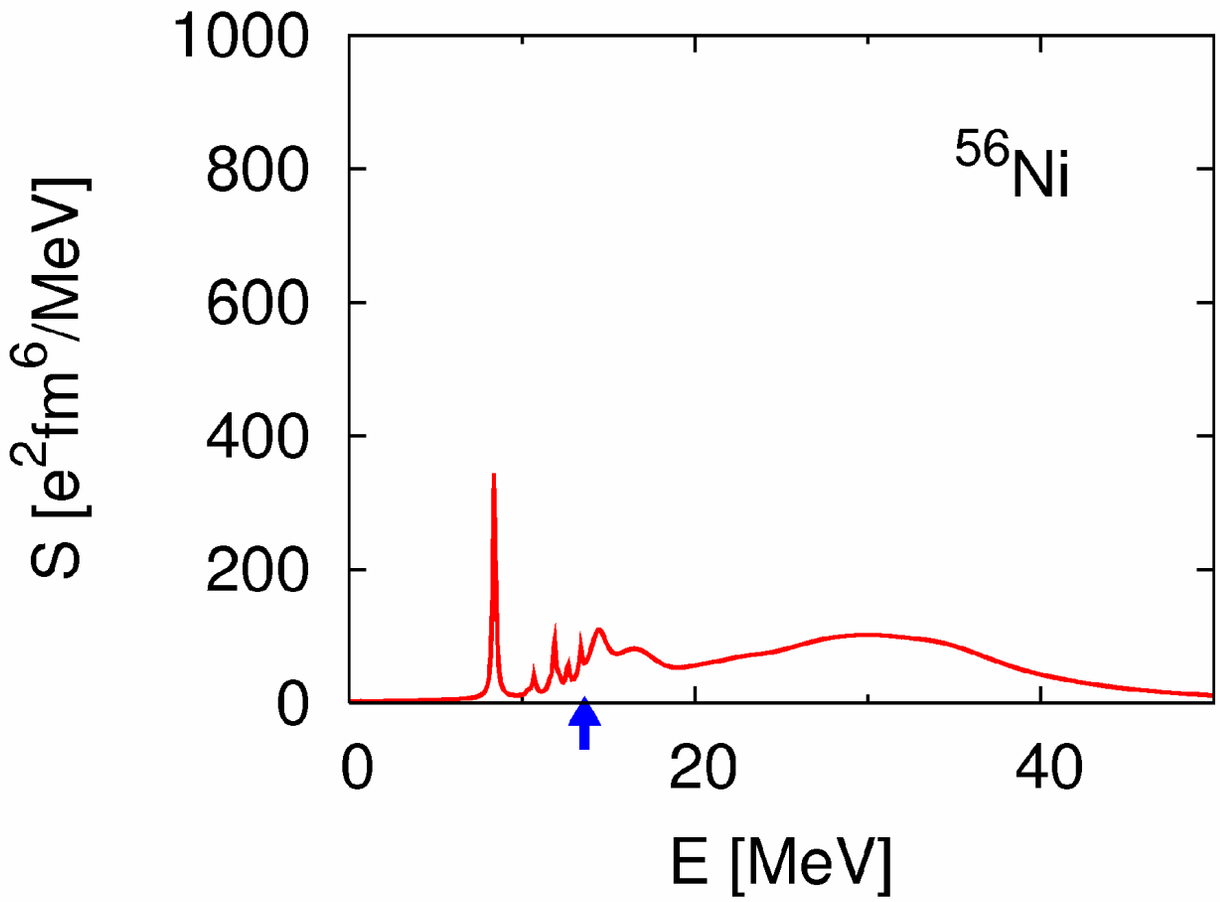

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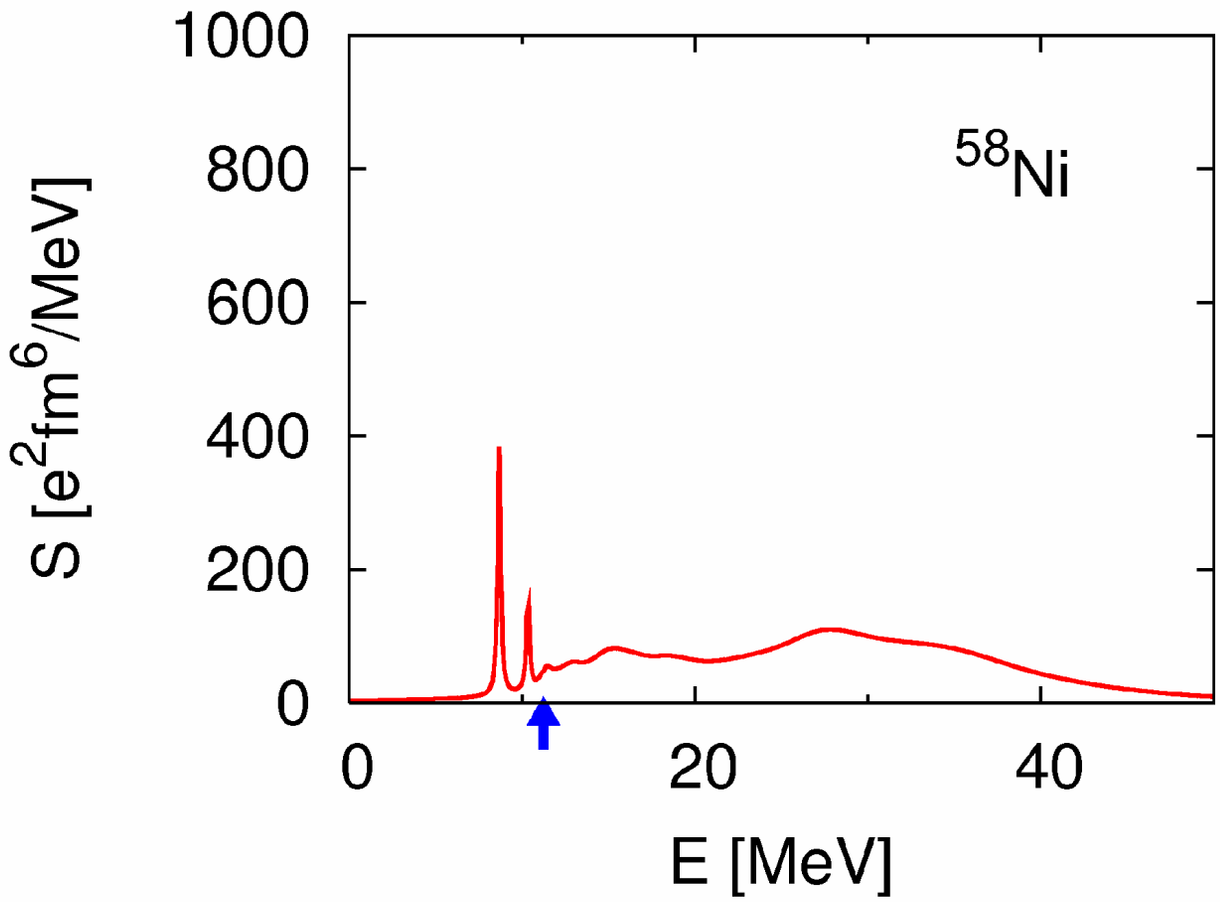

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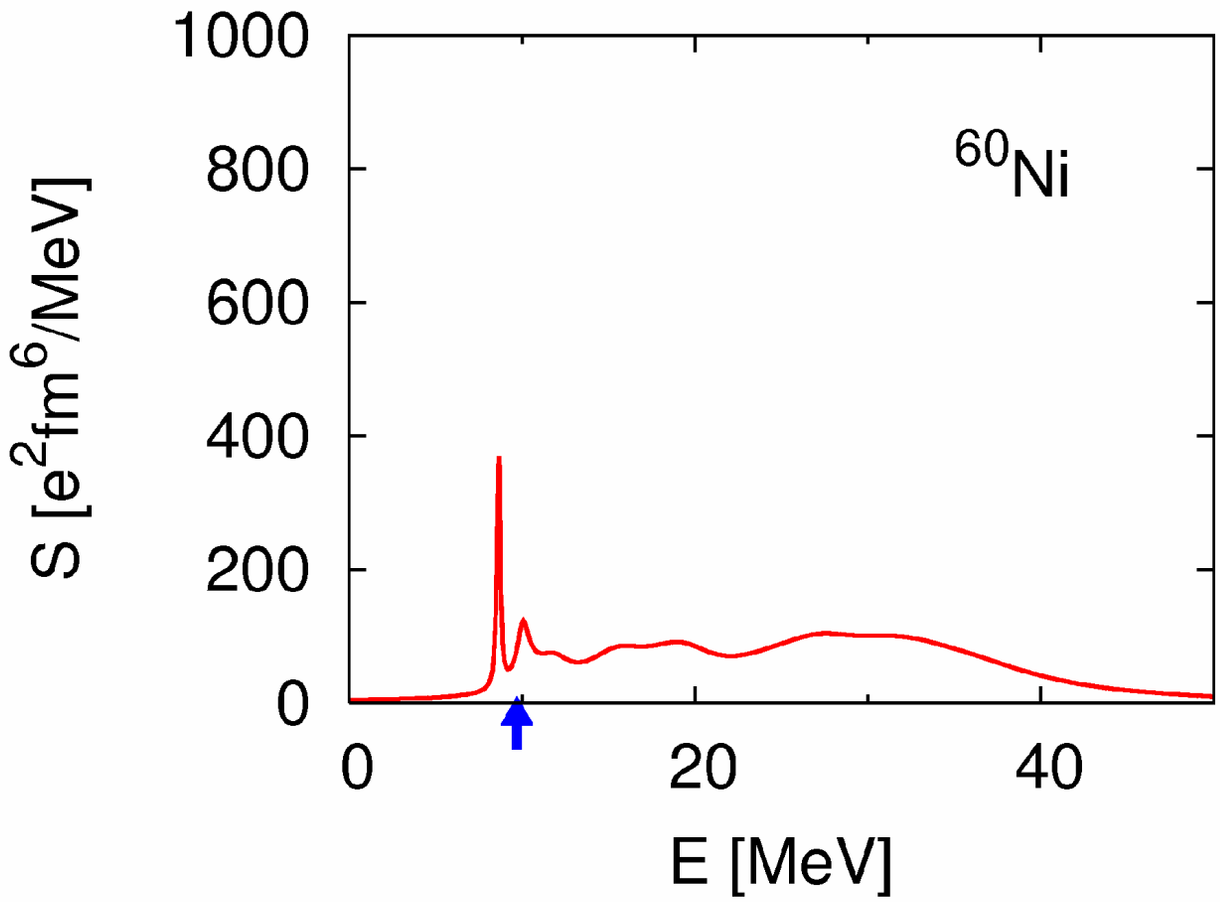

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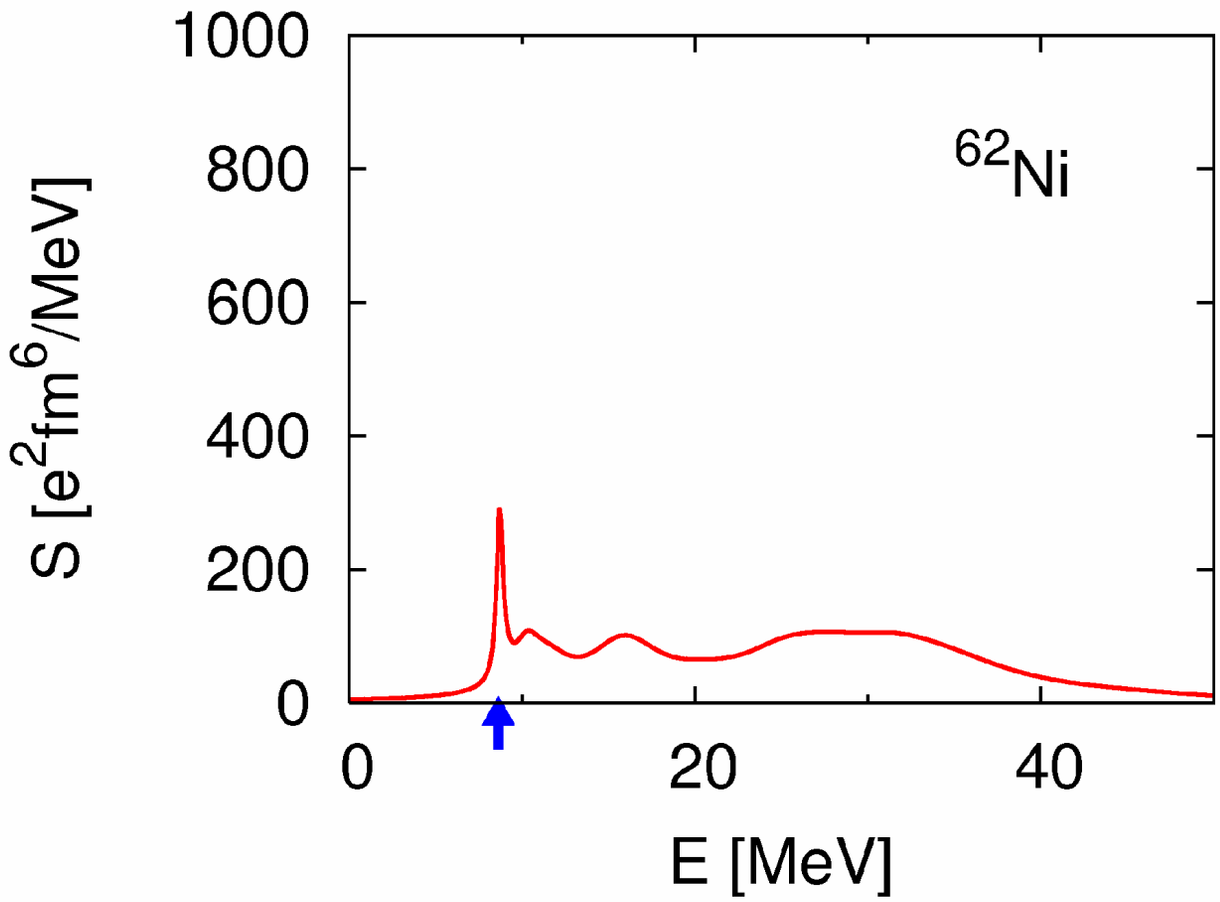

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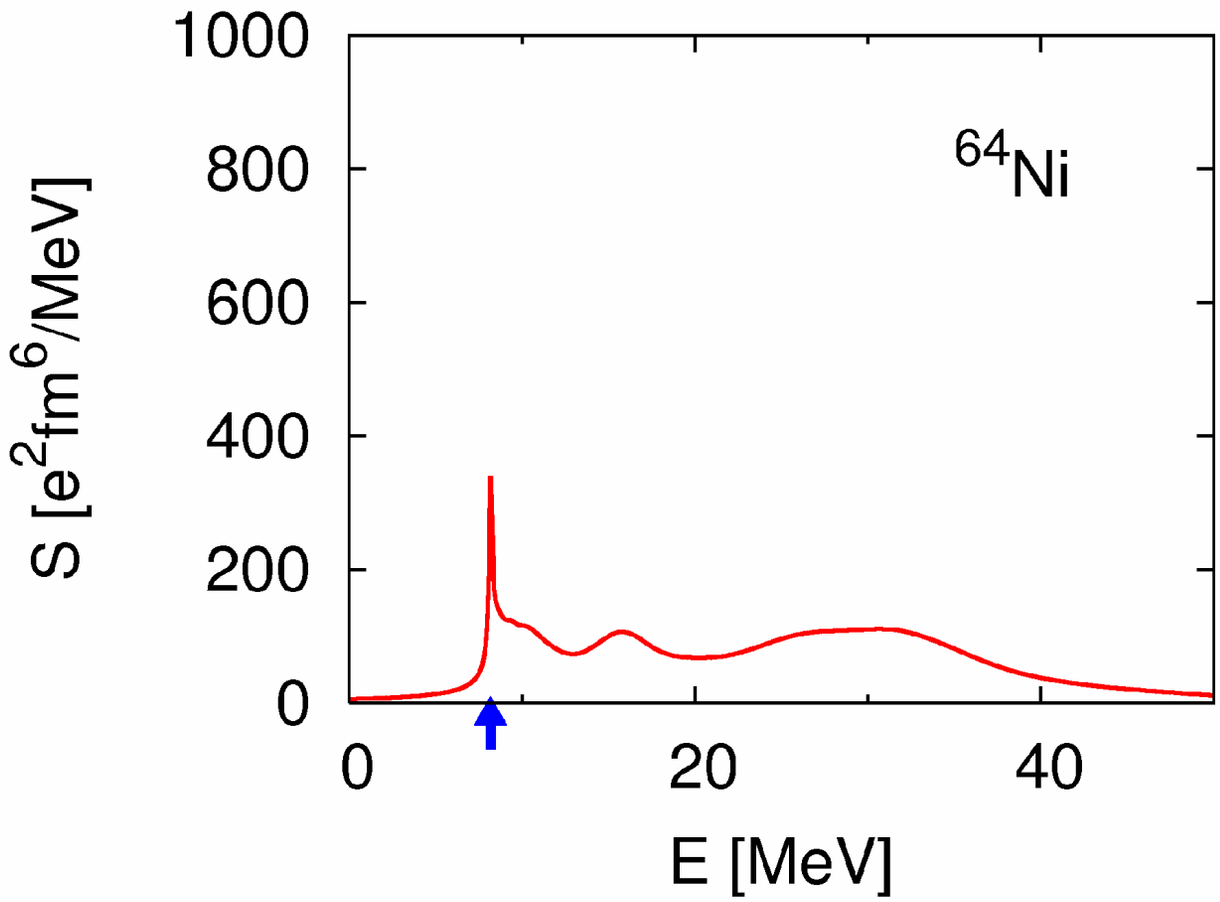

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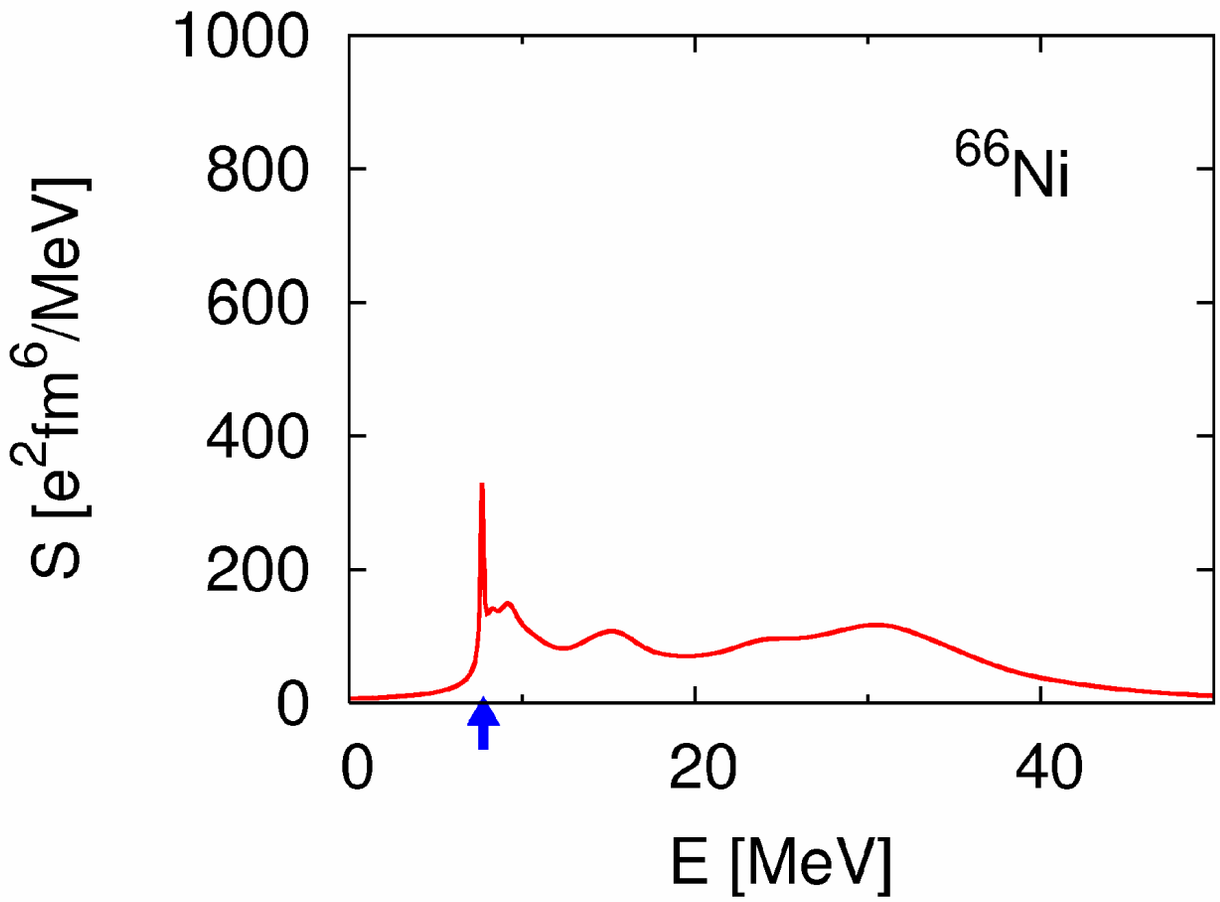

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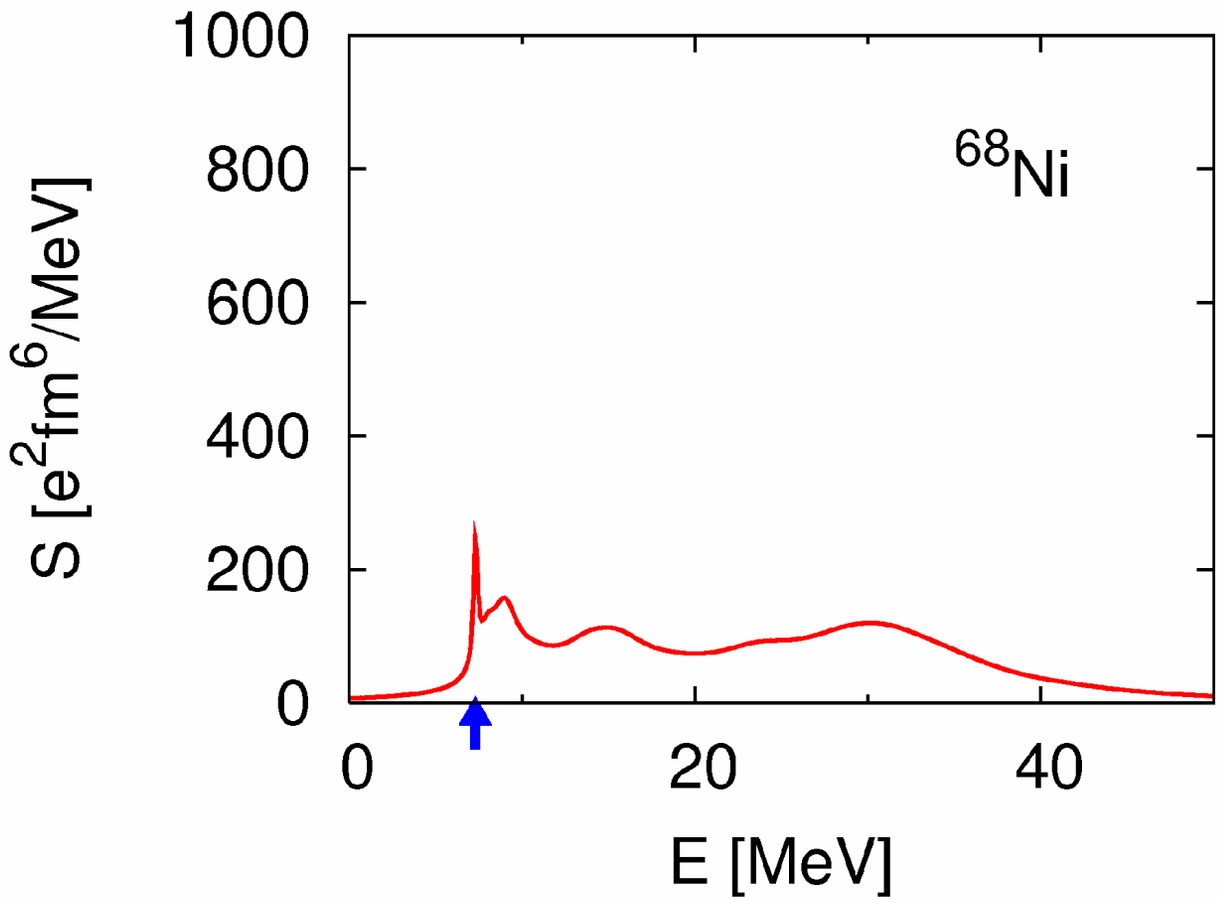

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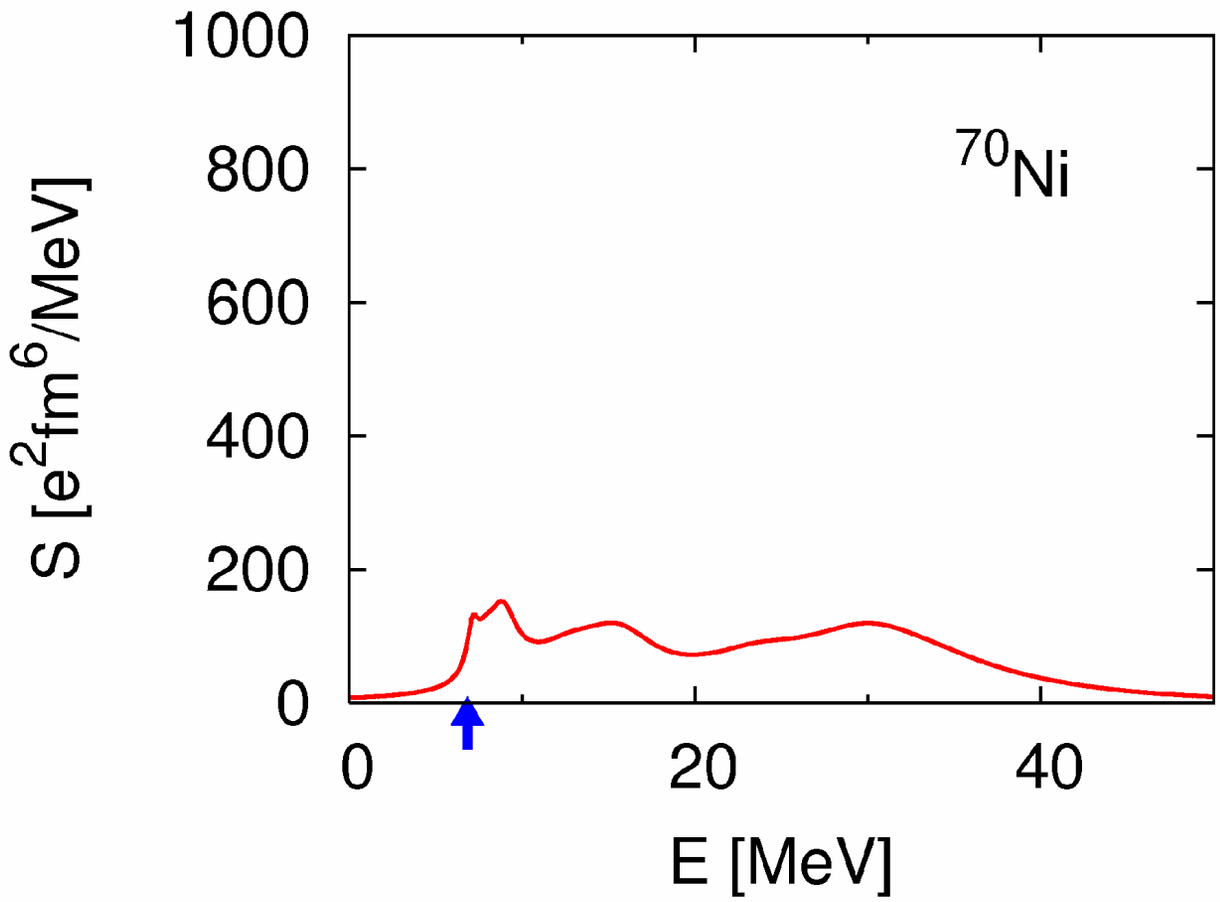

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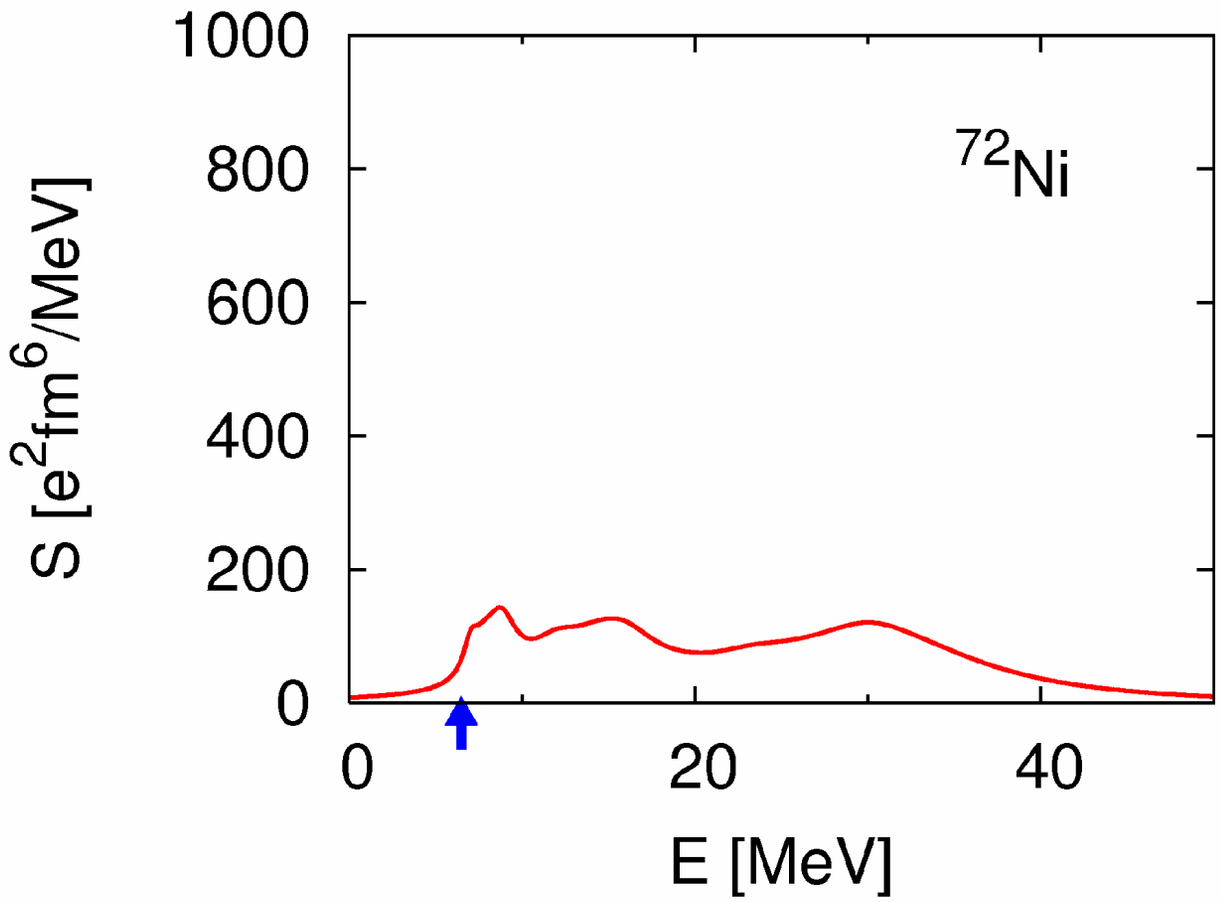

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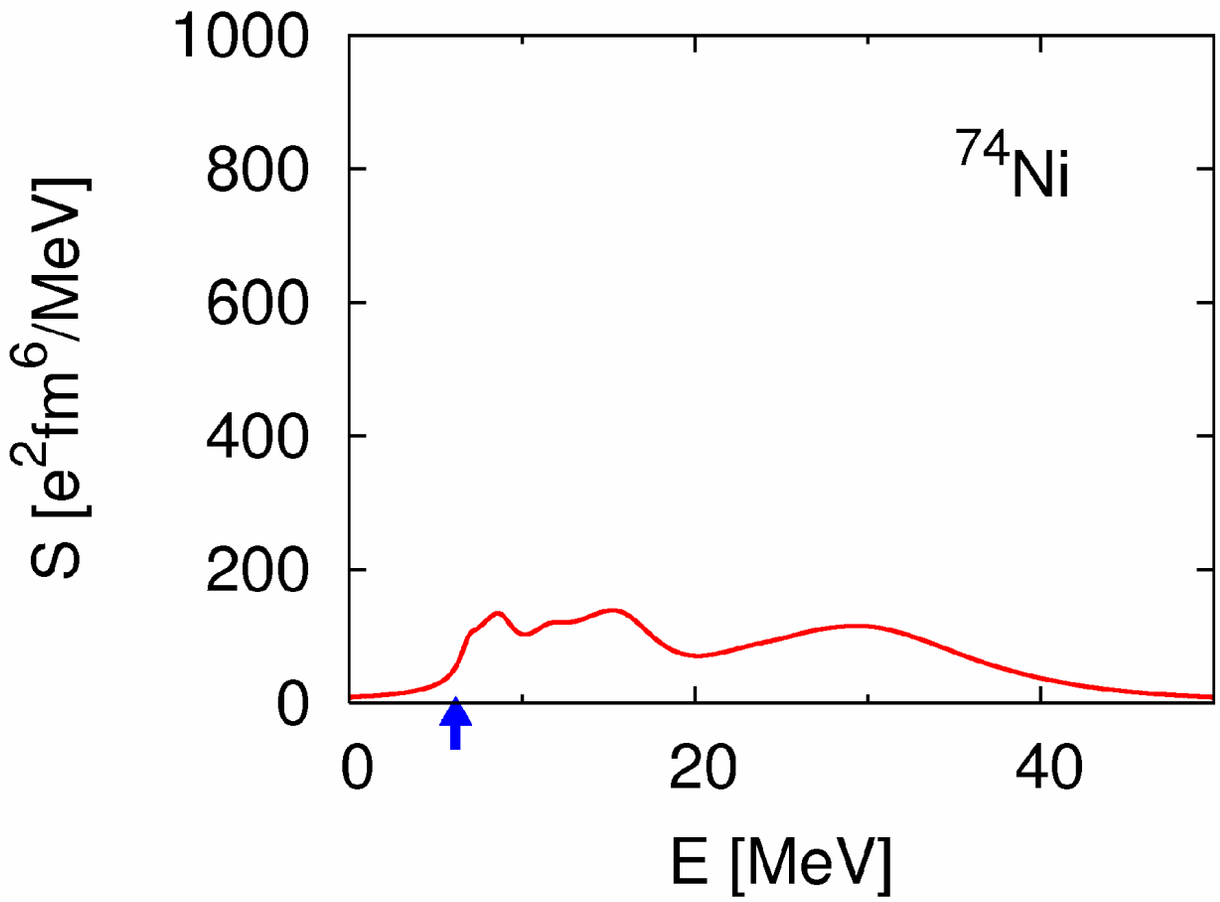

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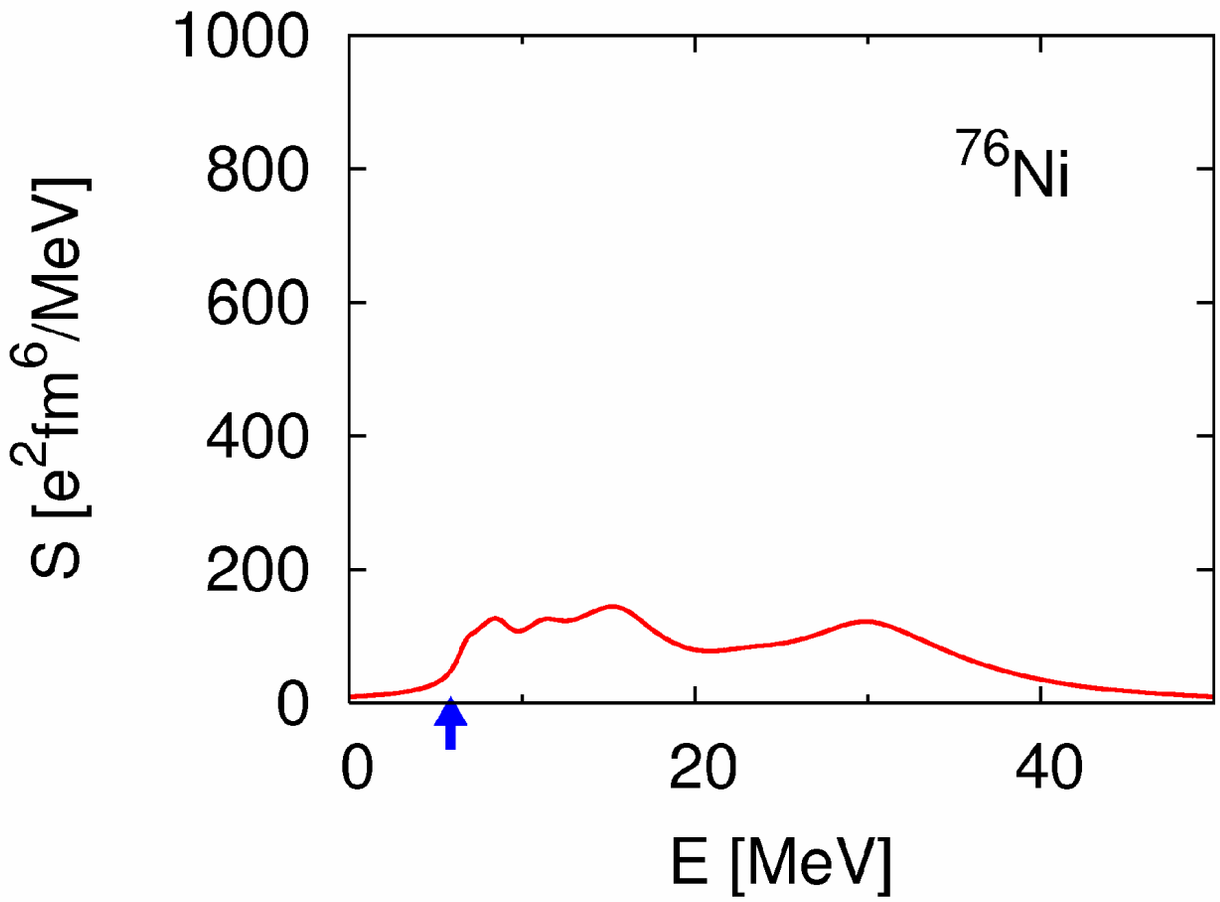

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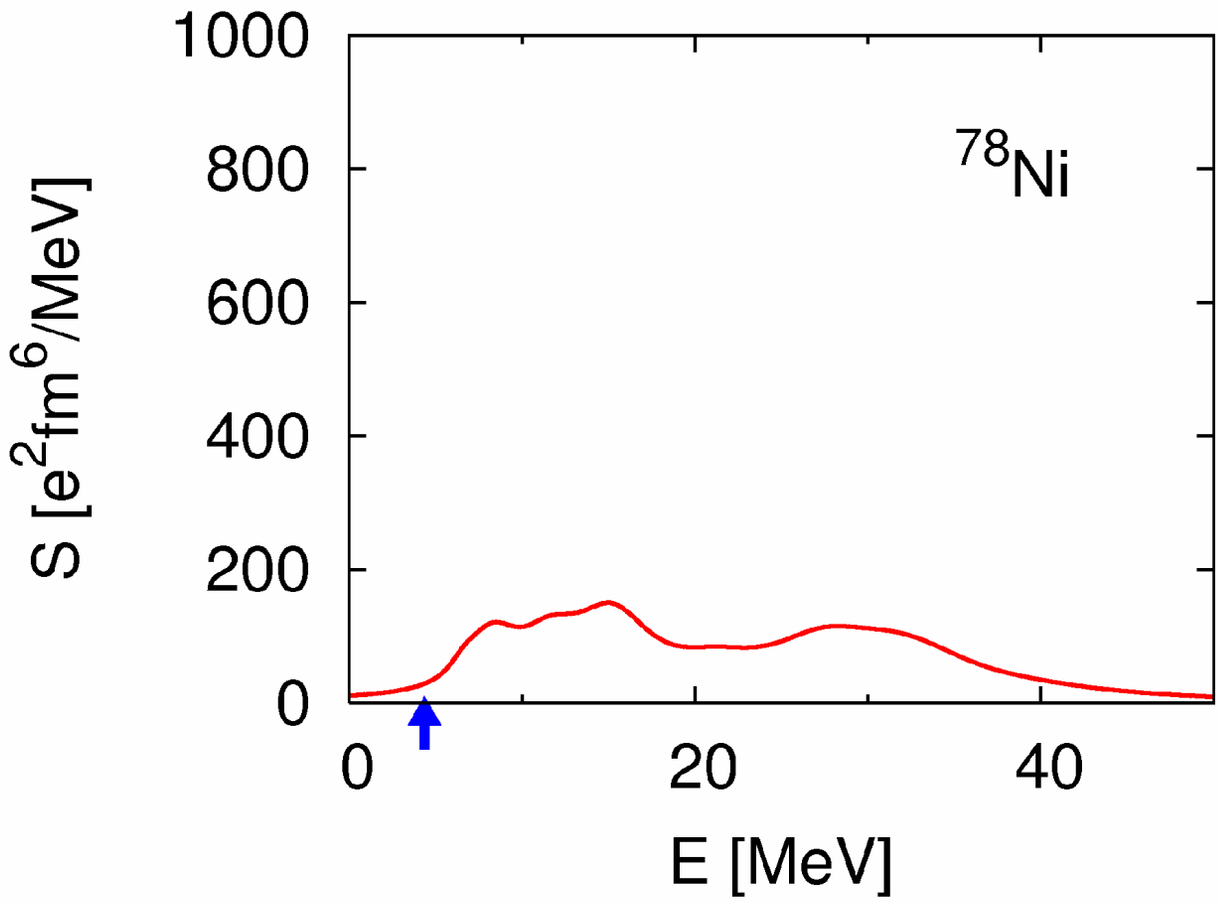

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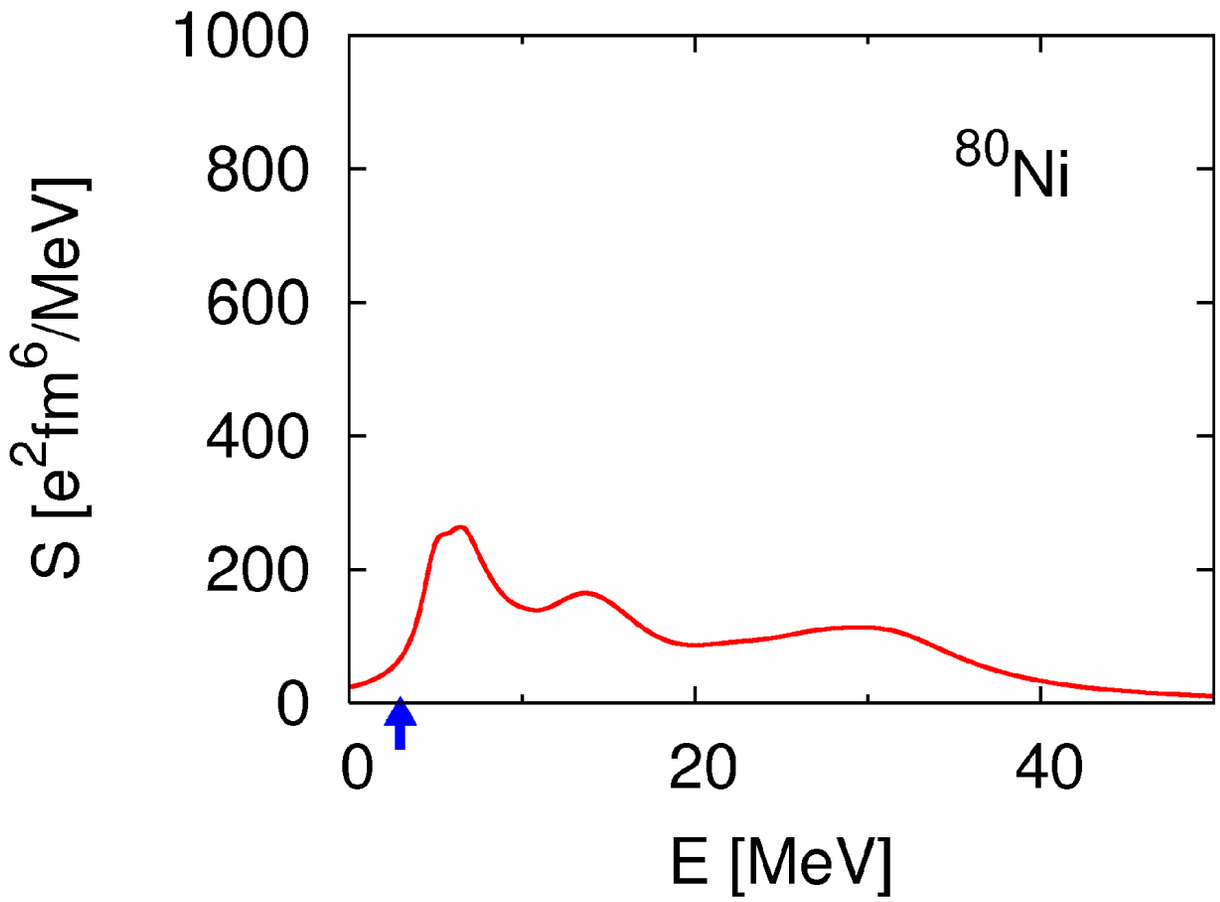

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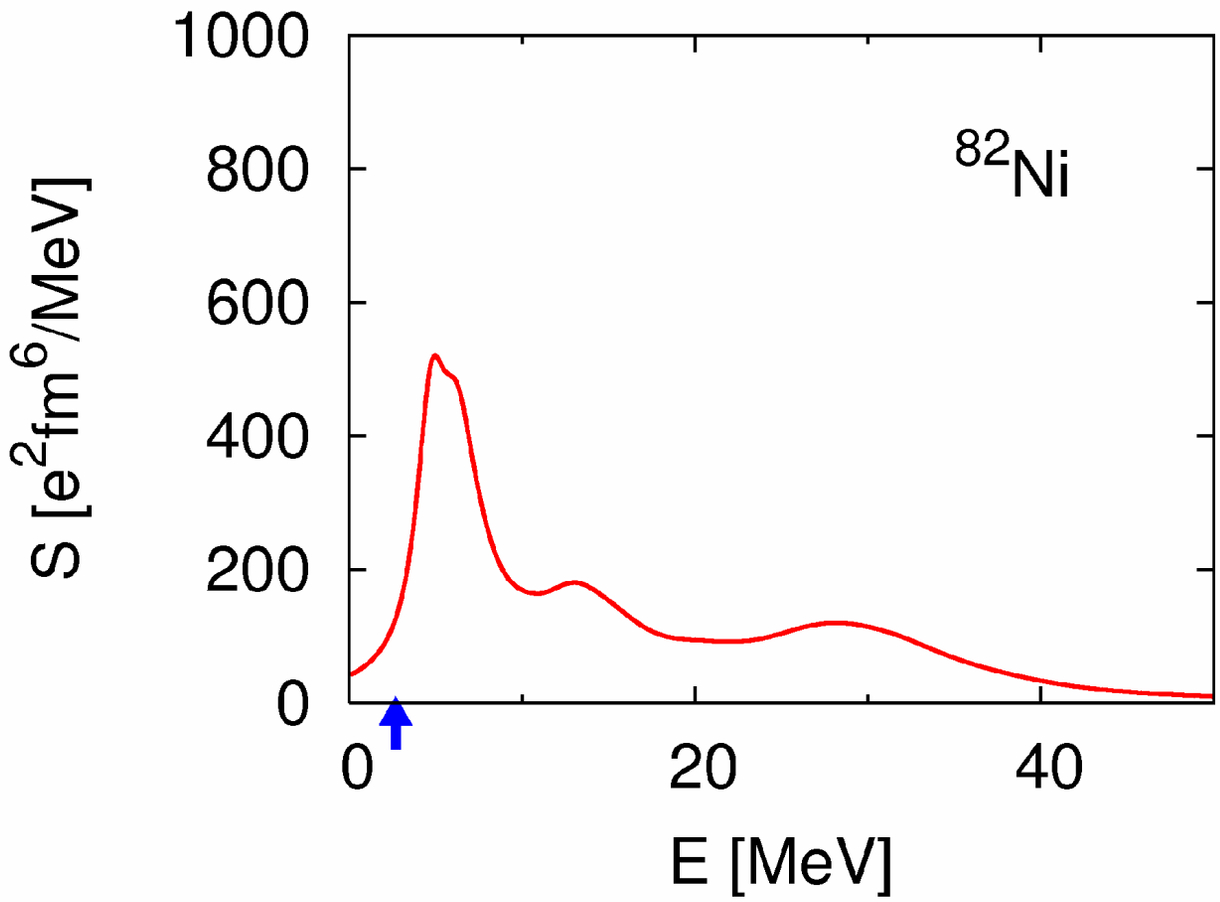
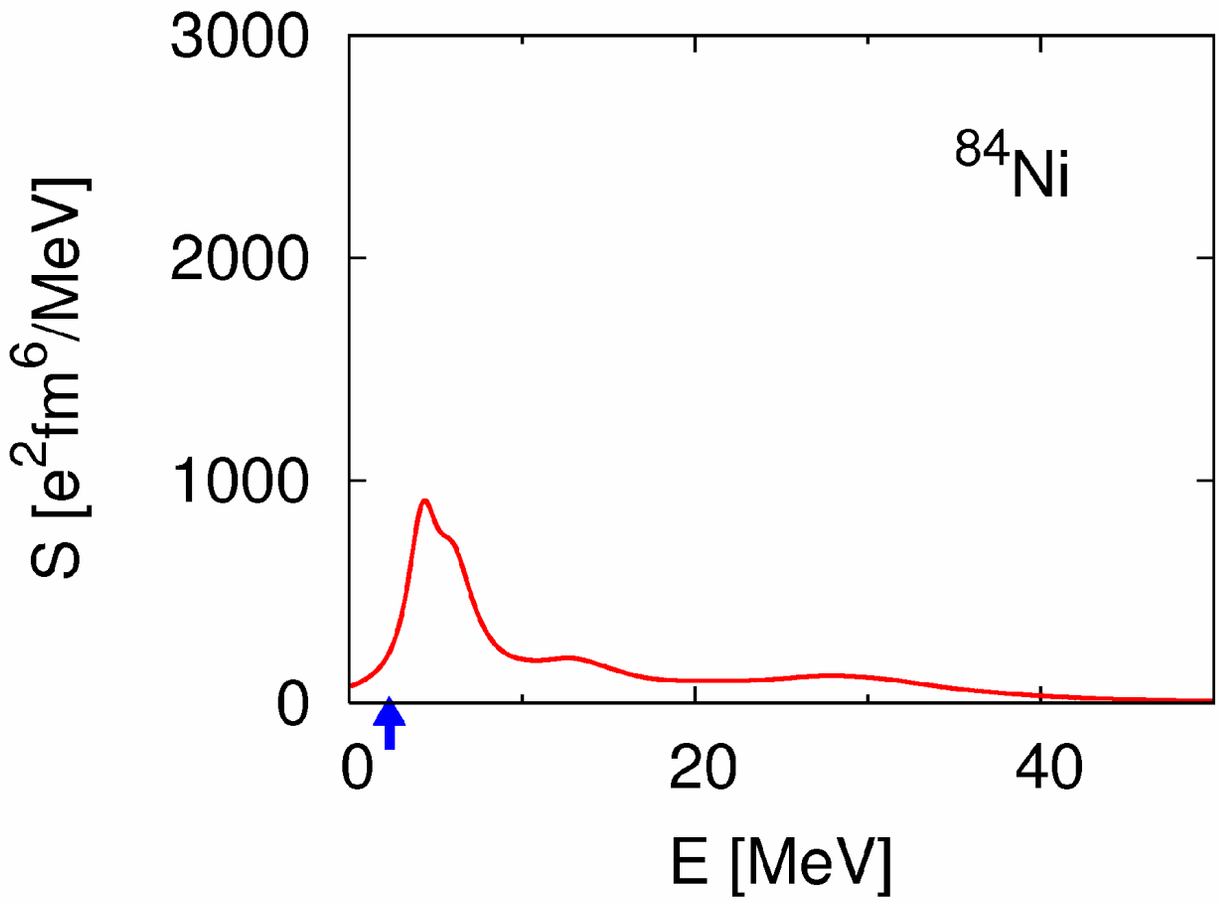


Isoscalar 1^- strength functions



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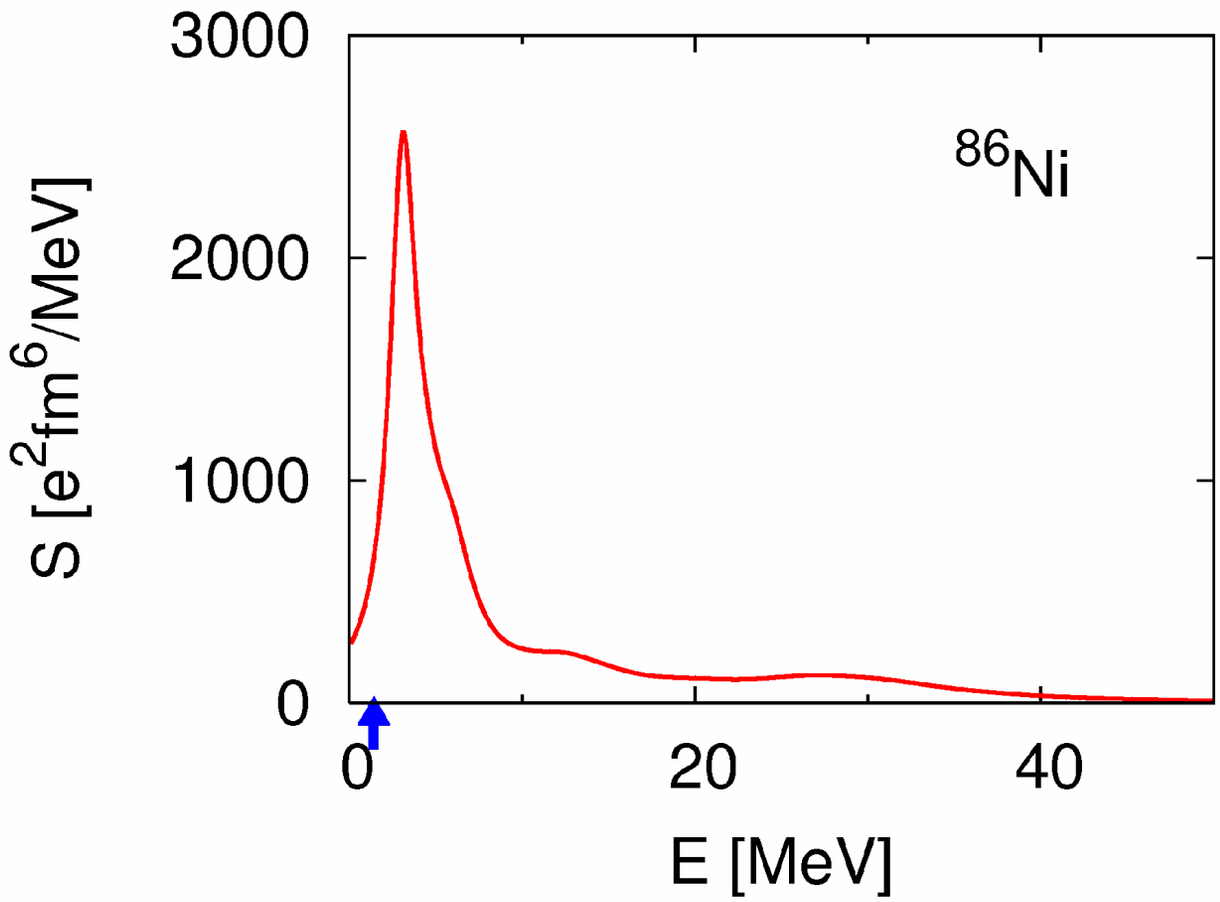

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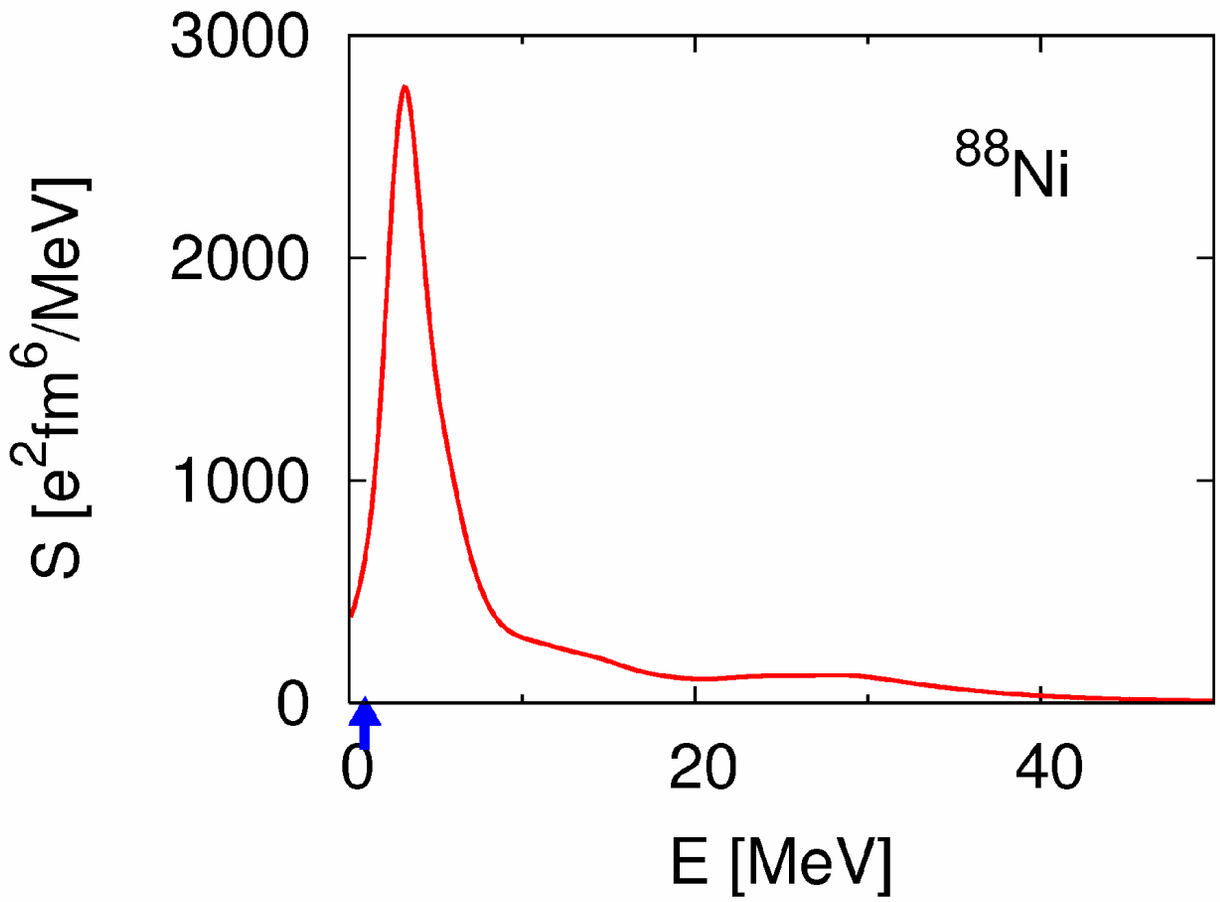
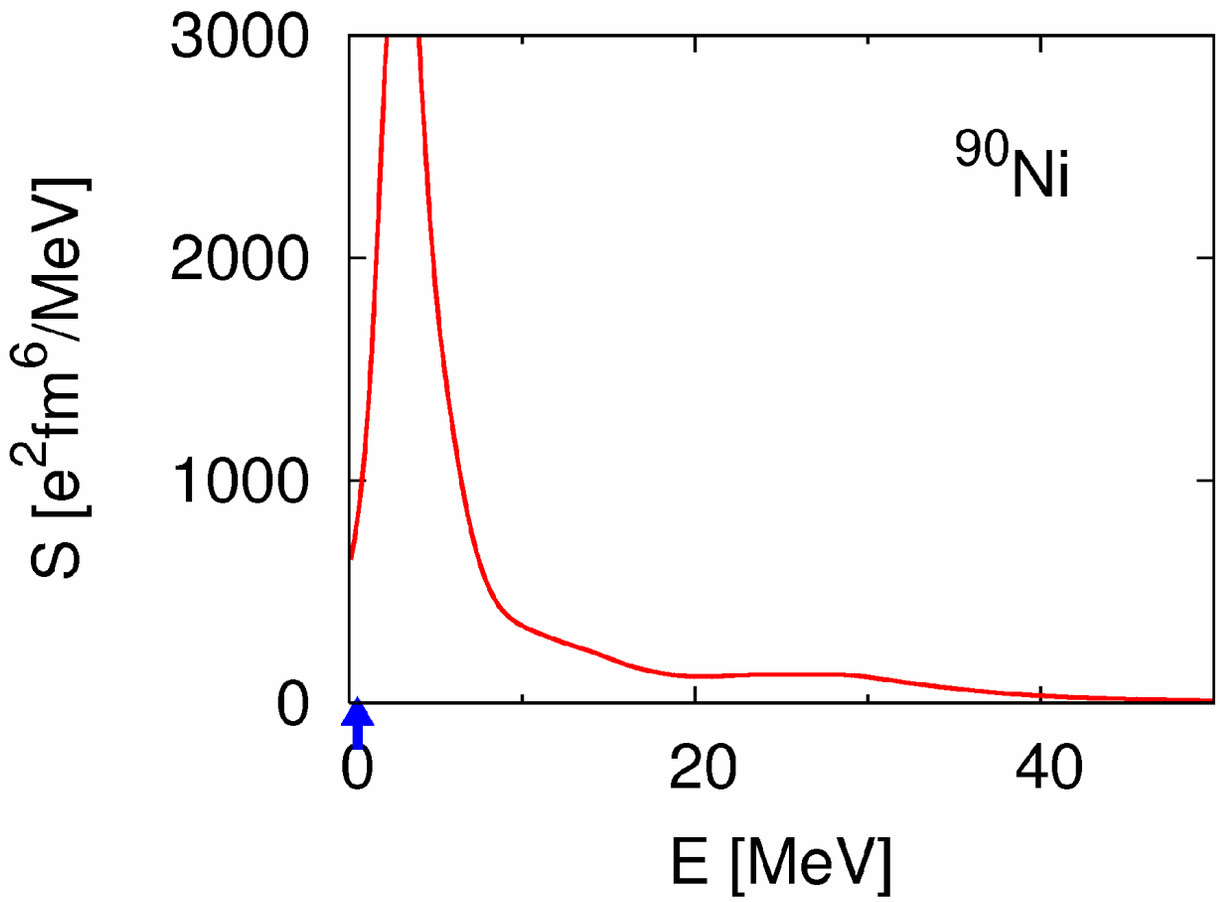


Isoscalar 1^- strength functions



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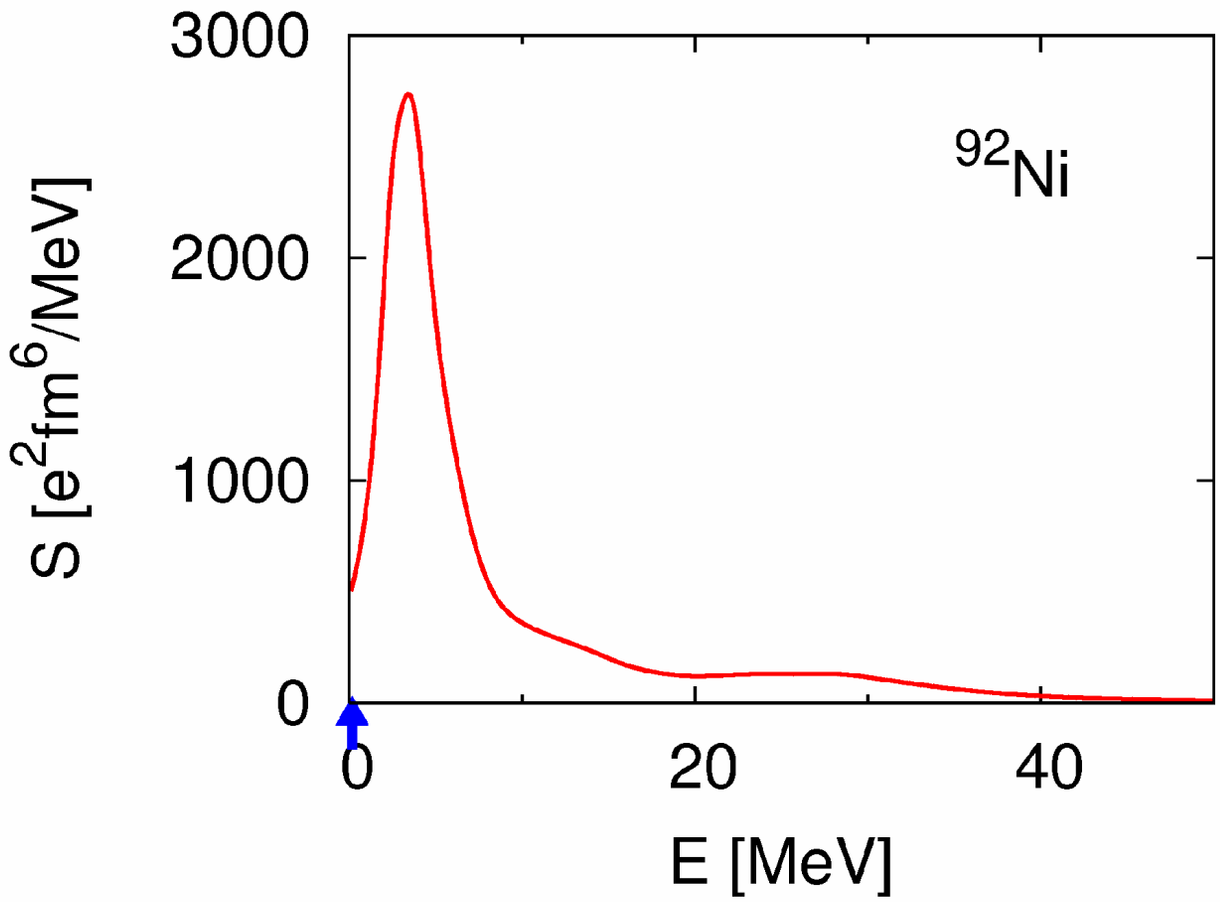

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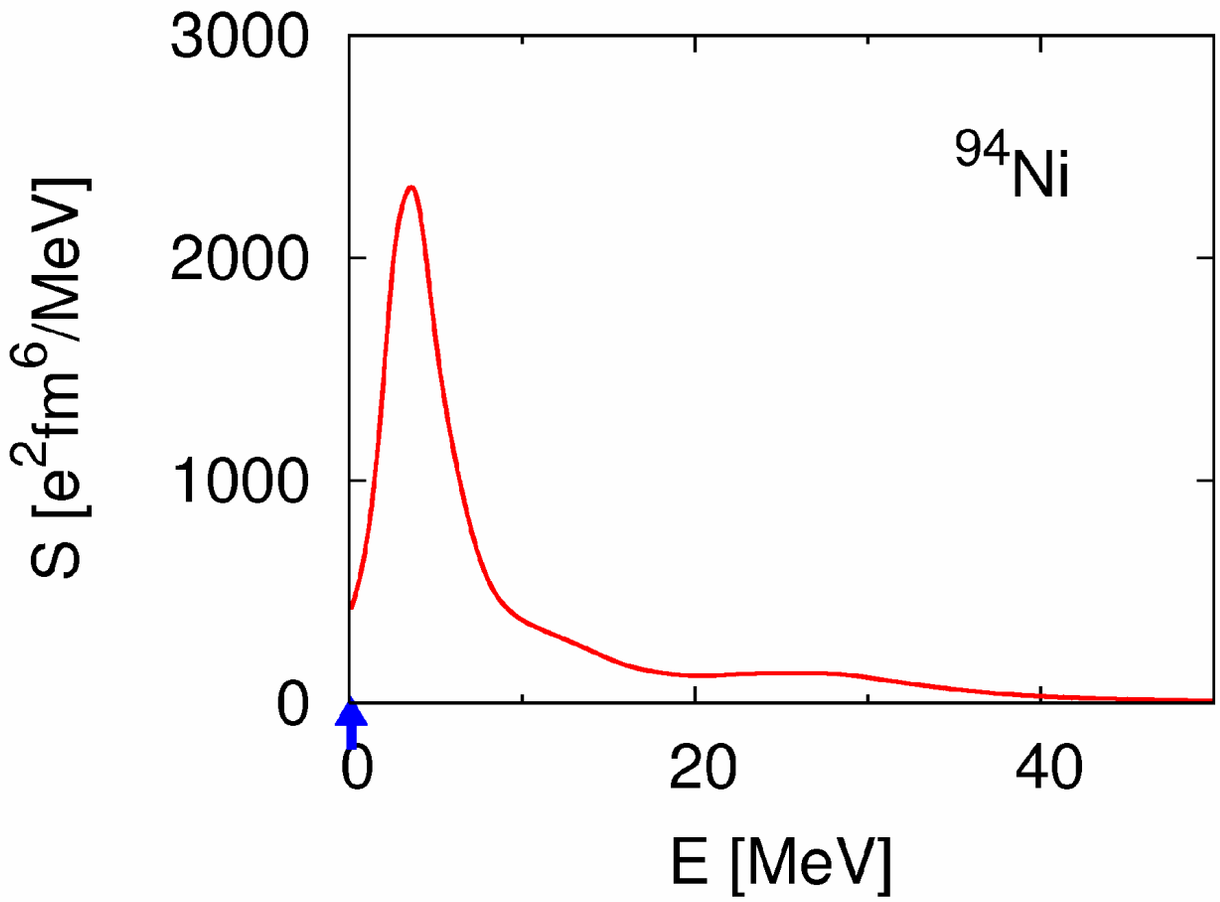

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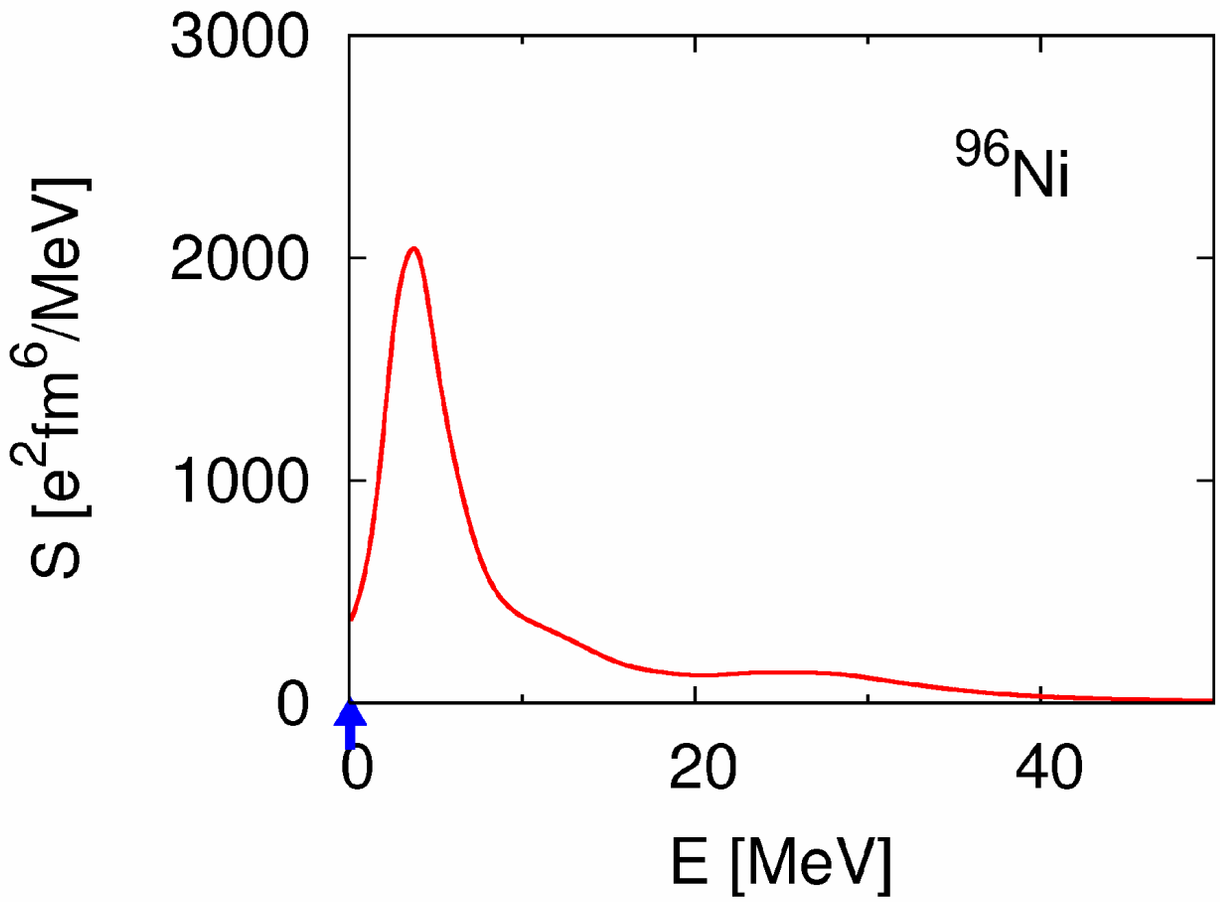
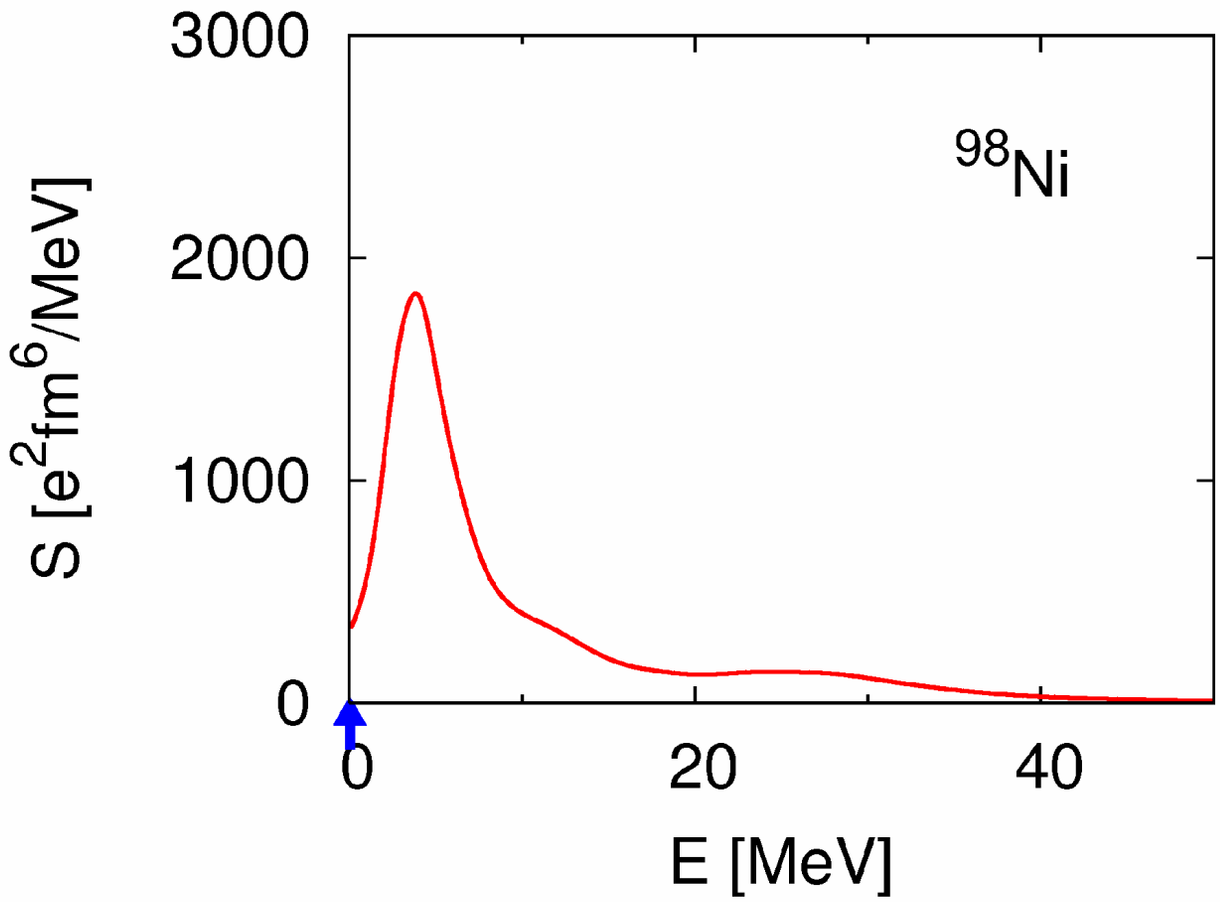
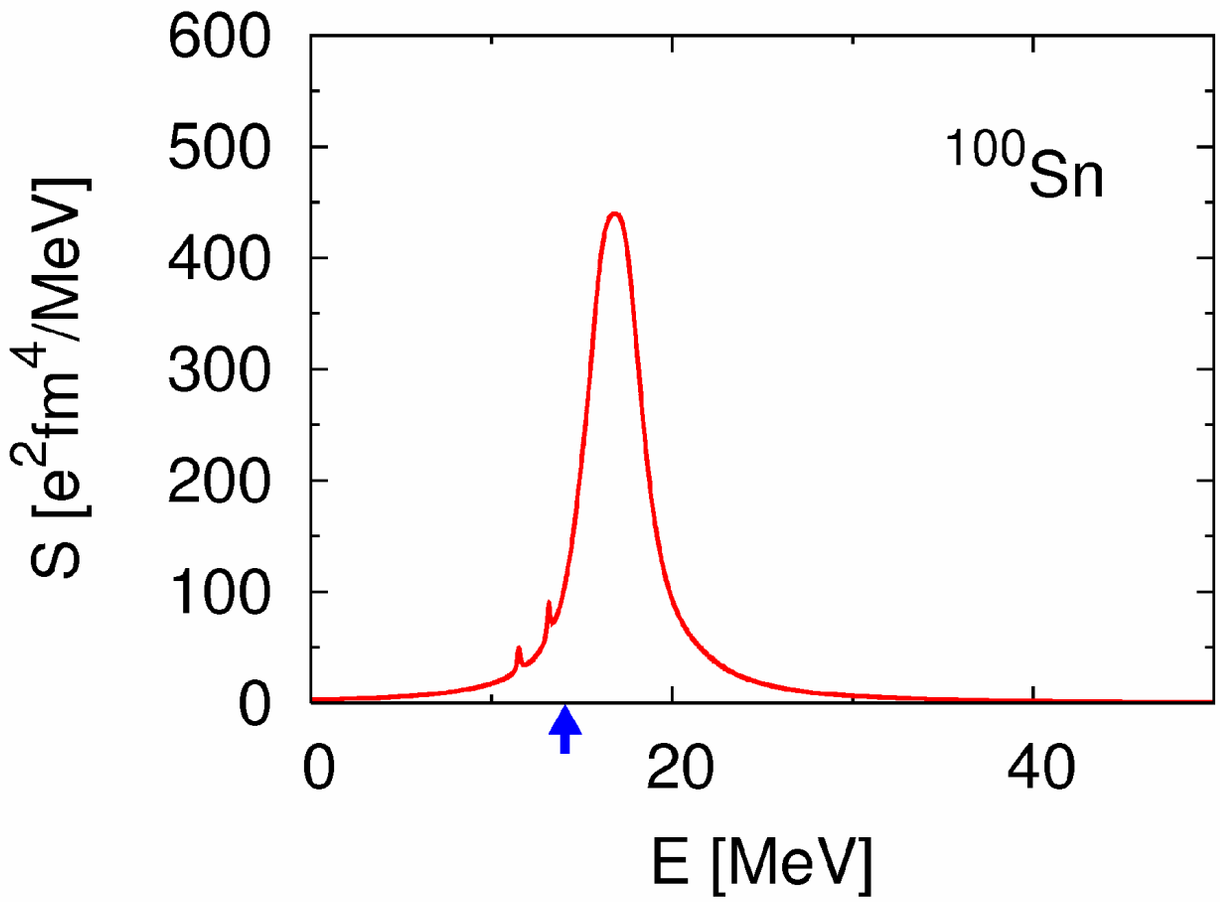


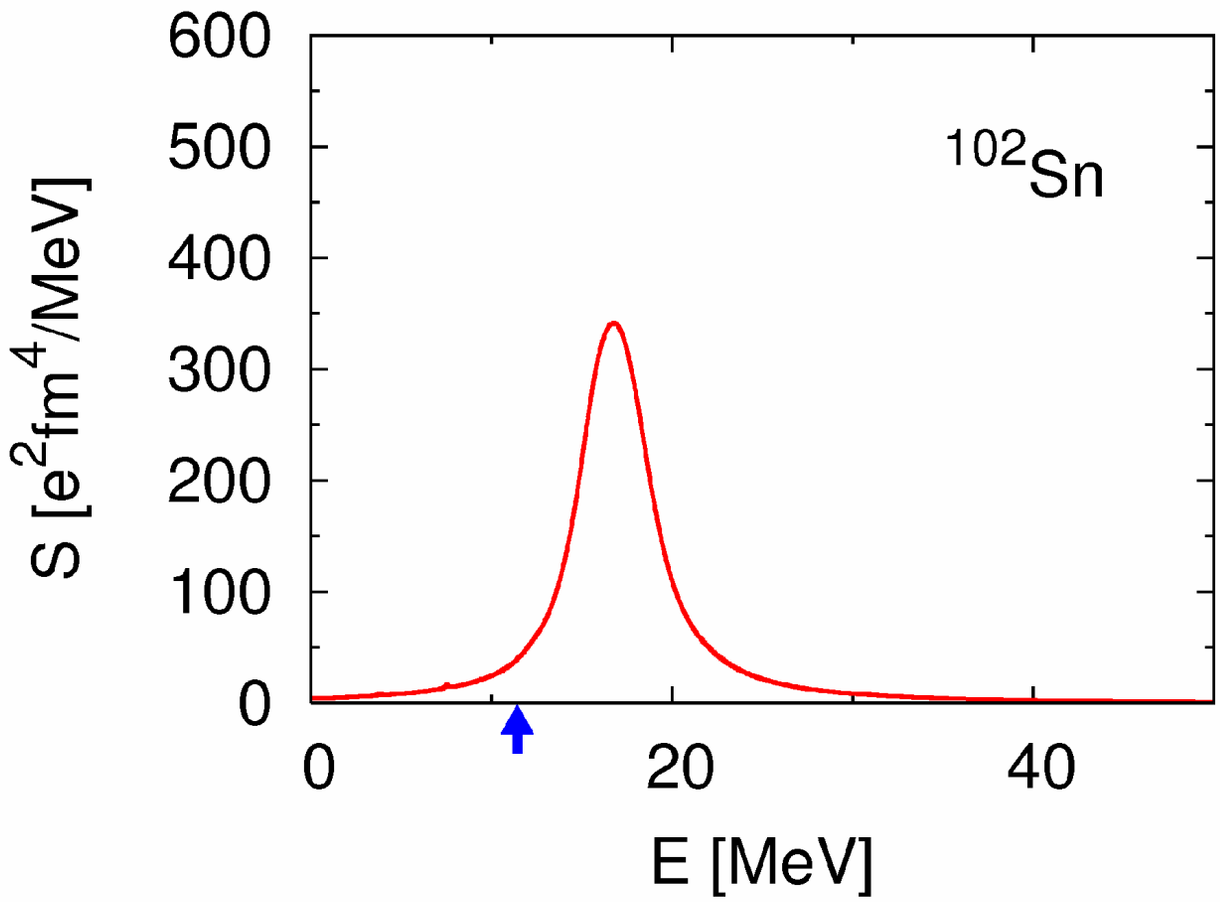
Isoscalar 1^- strength functions



Isoscalar 0^+ strength functions



Isoscalar 0^+ strength functions



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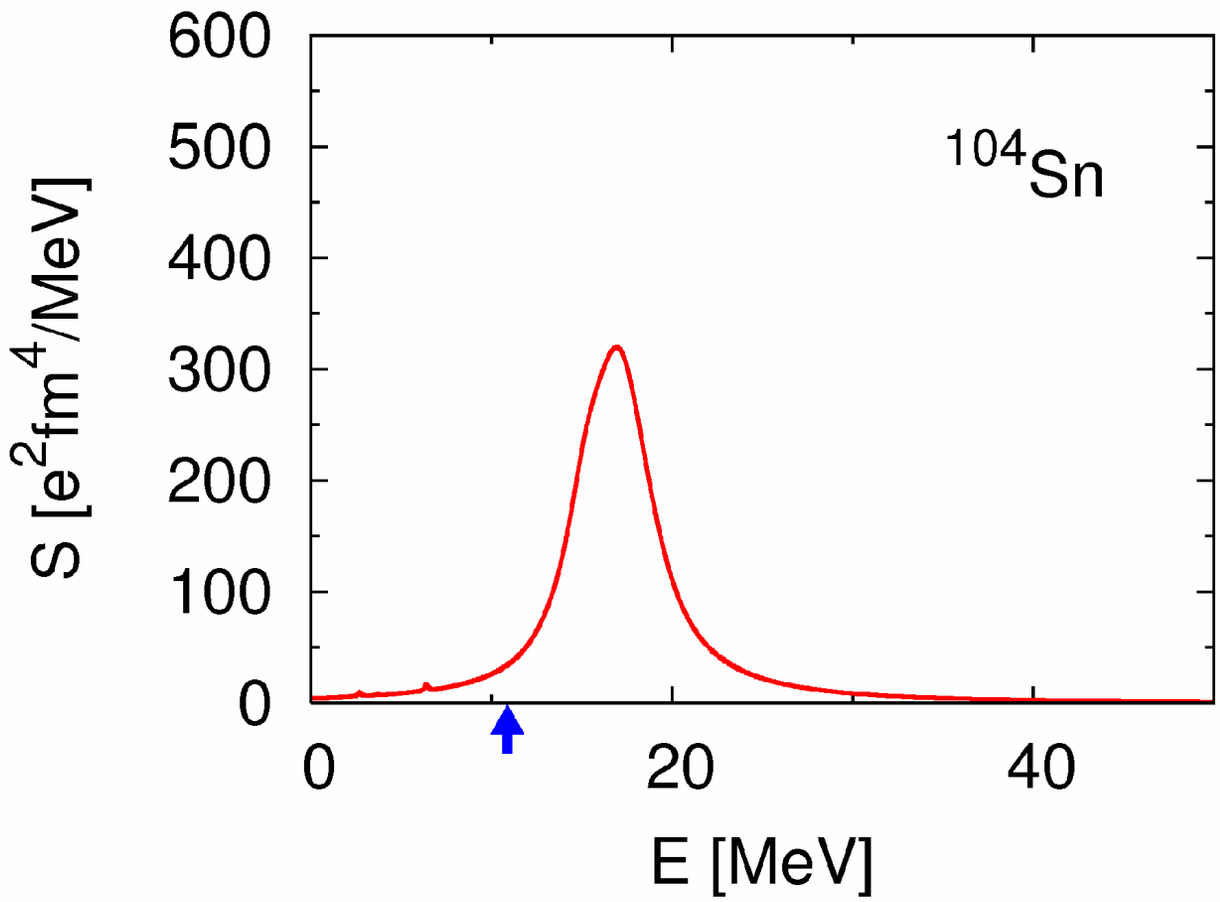

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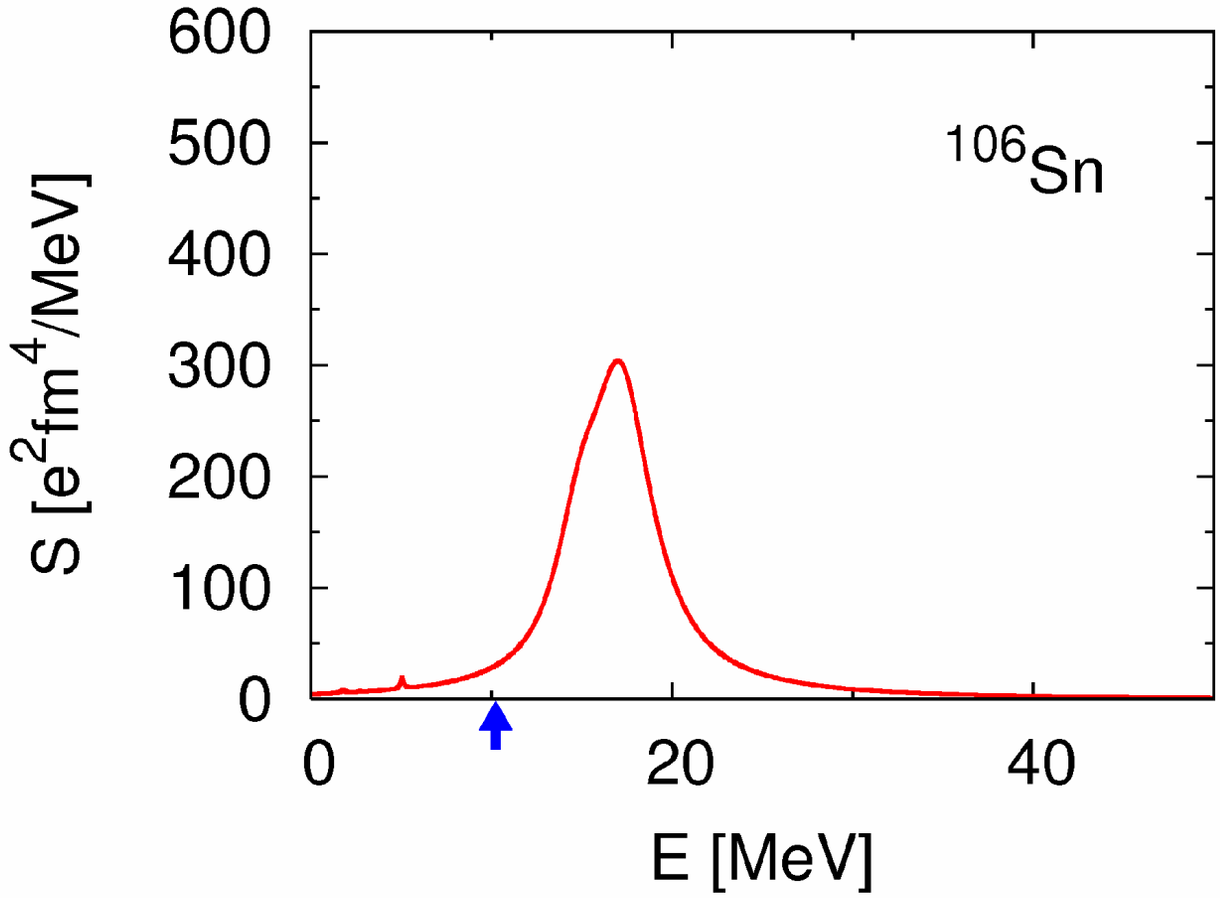

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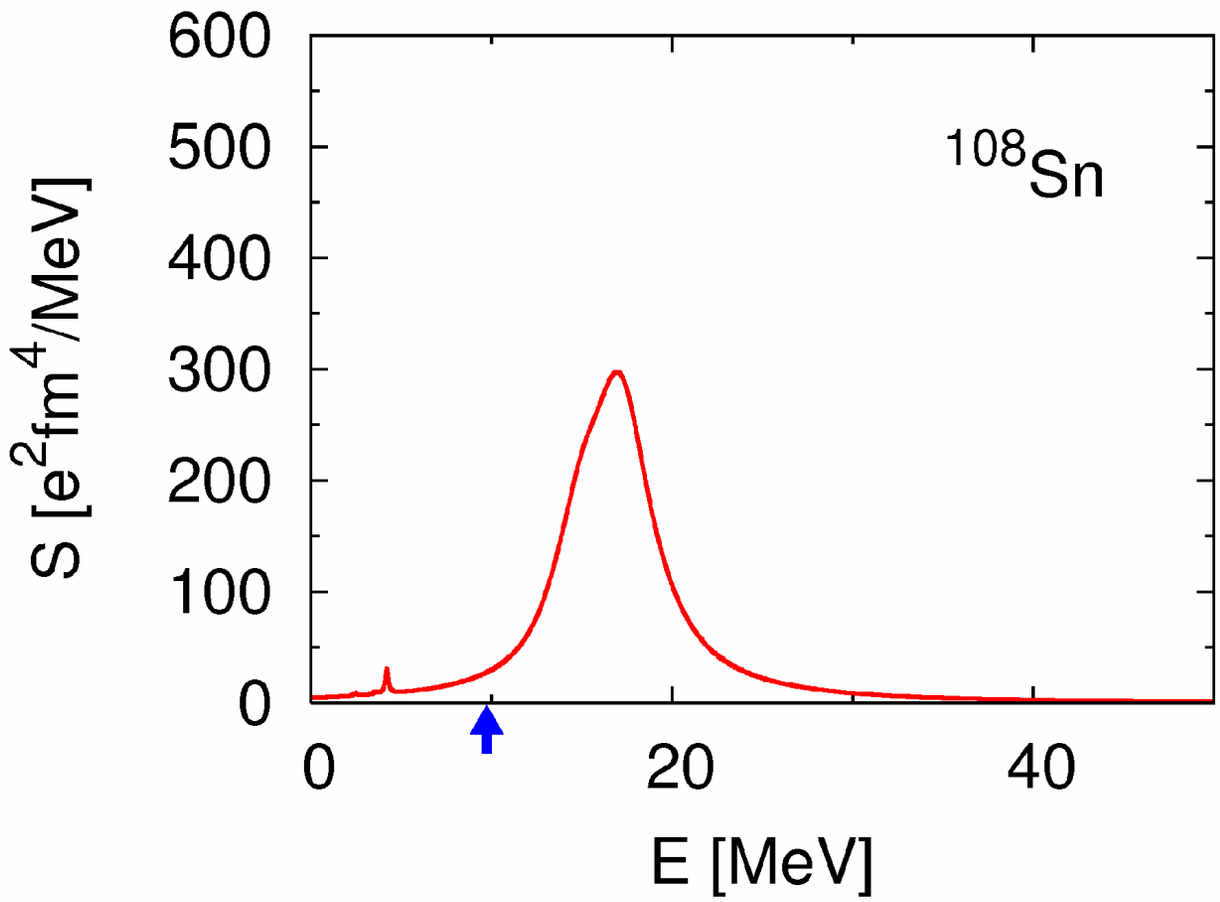

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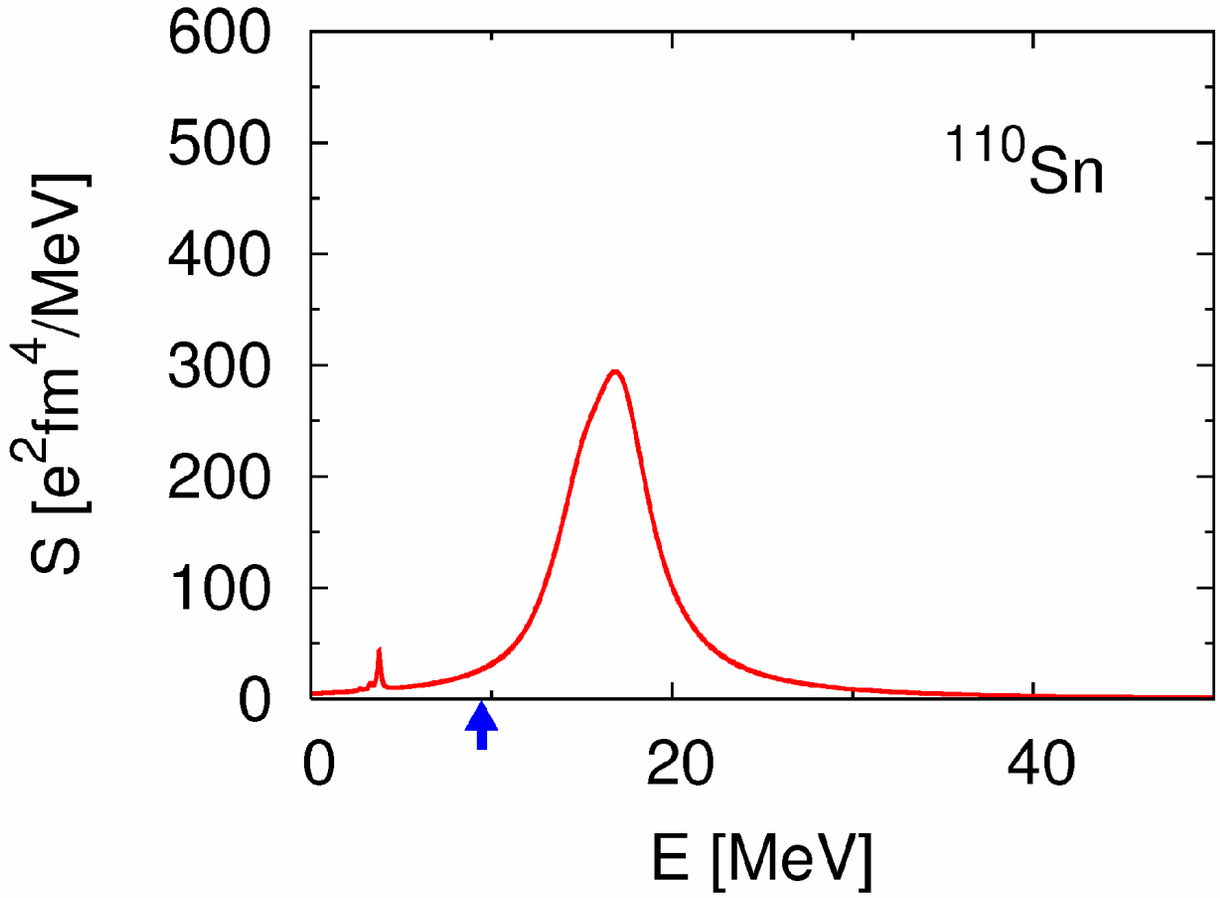
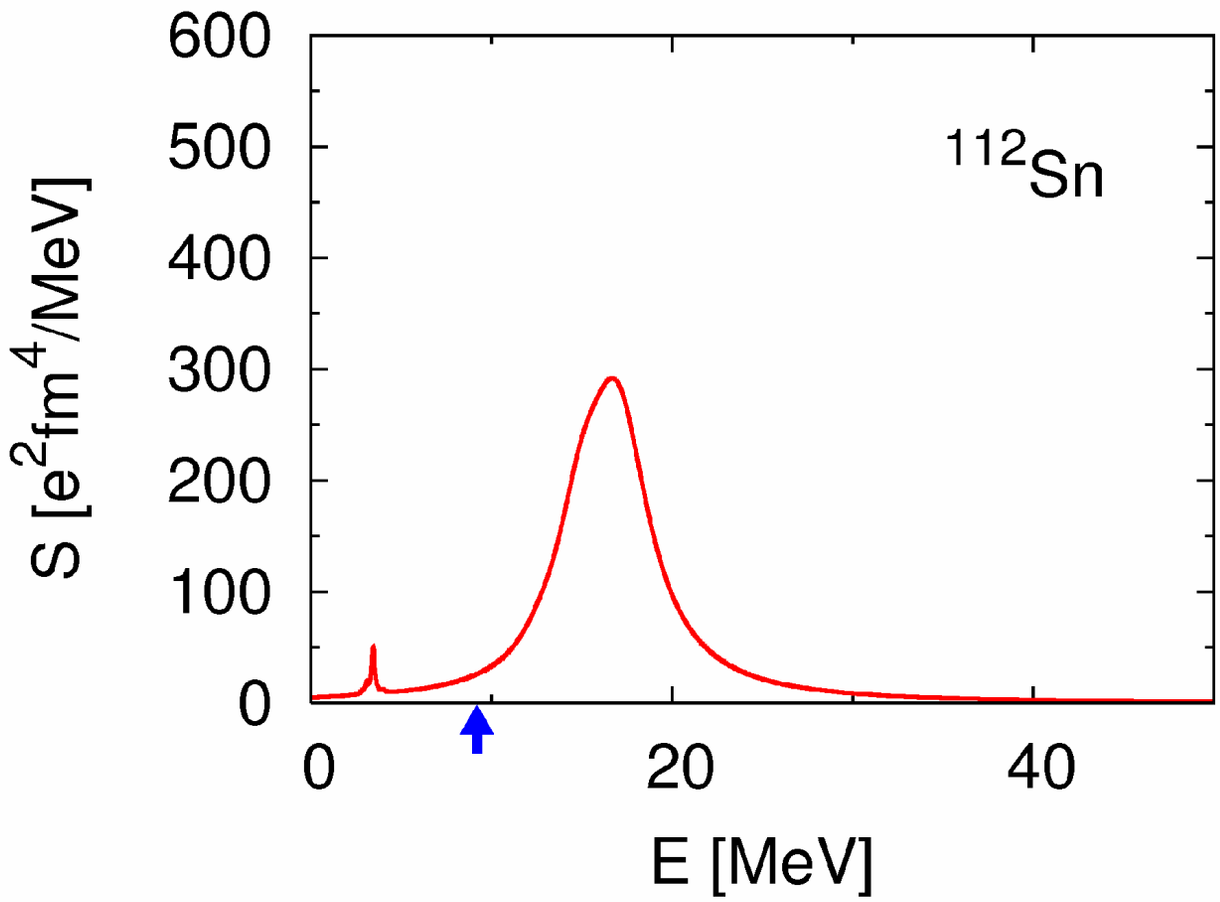
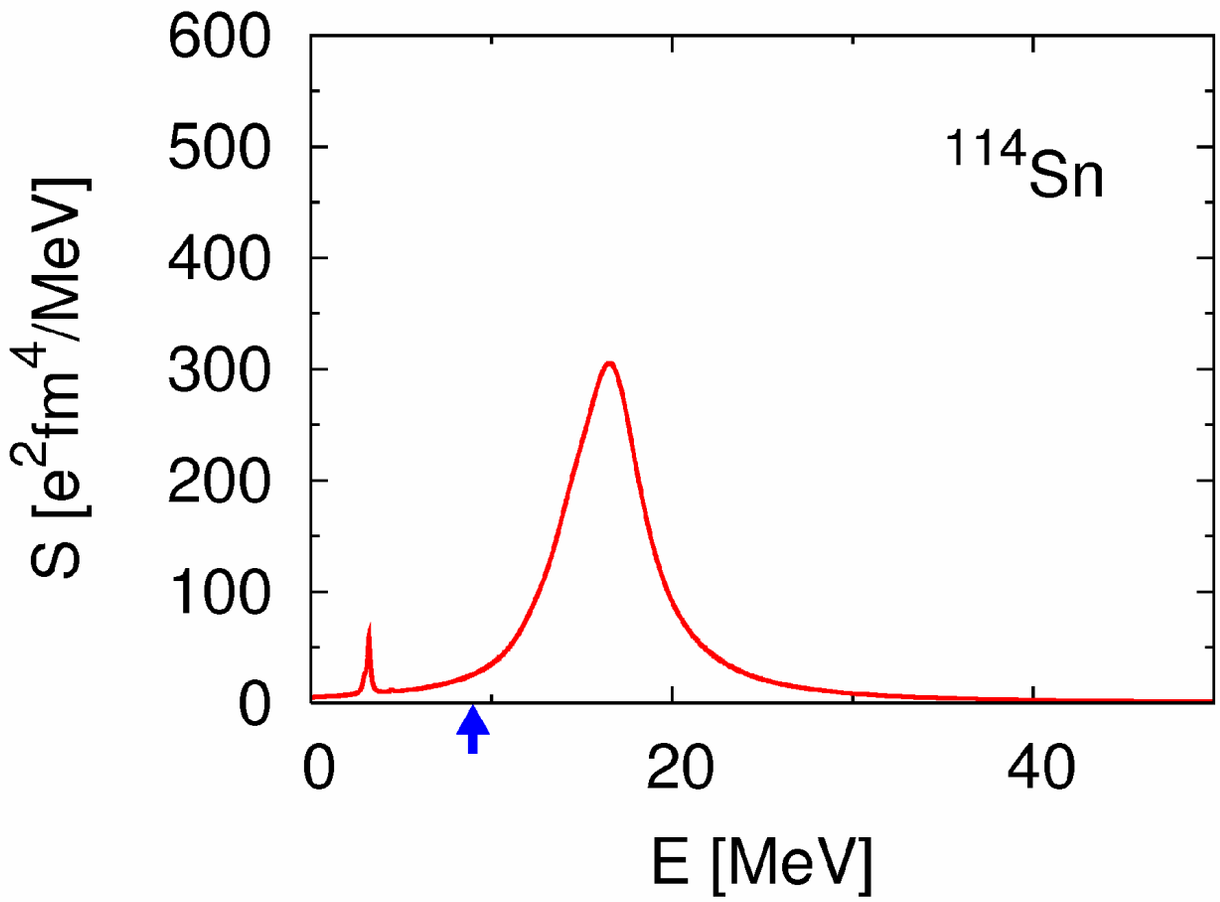


Isoscalar 0^+ strength functions



Isoscalar 0^+ strength functions



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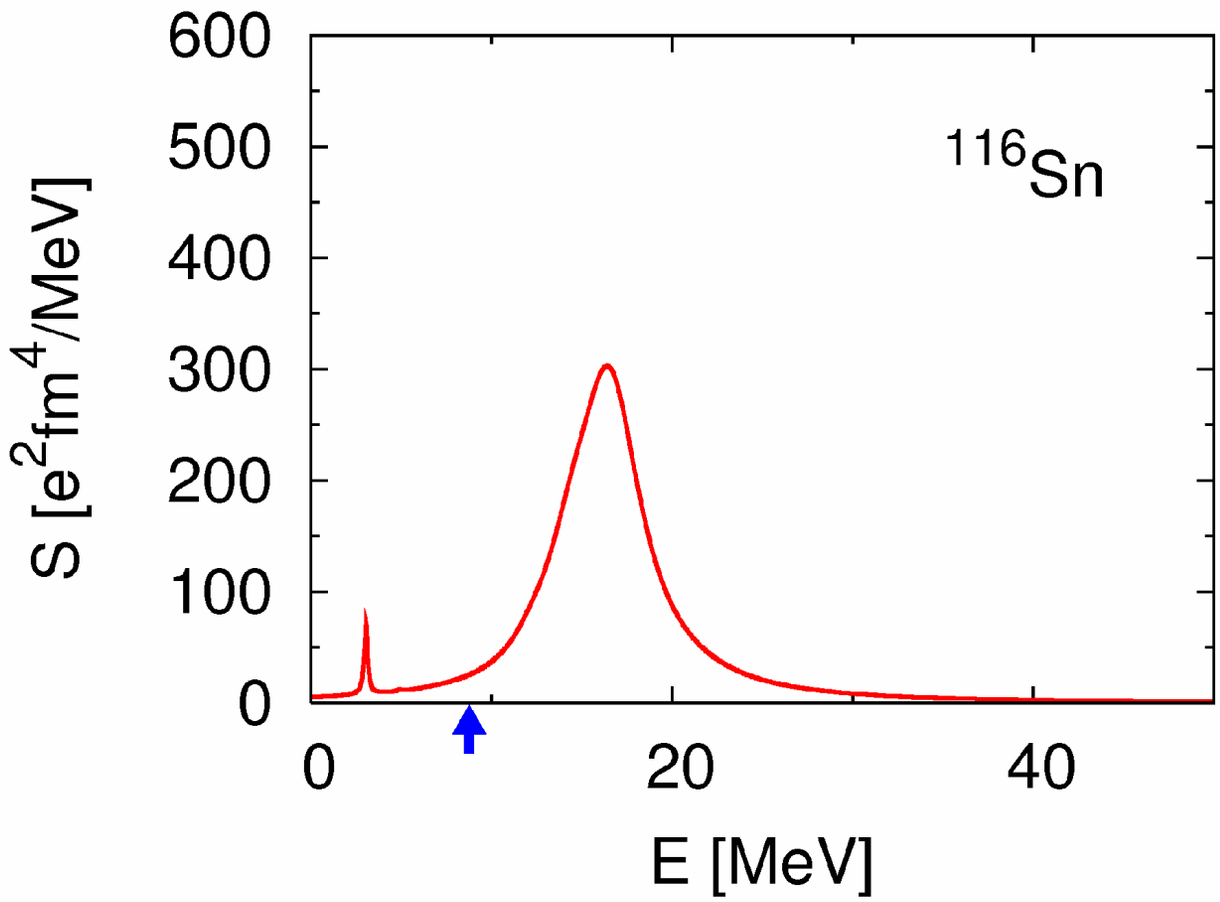
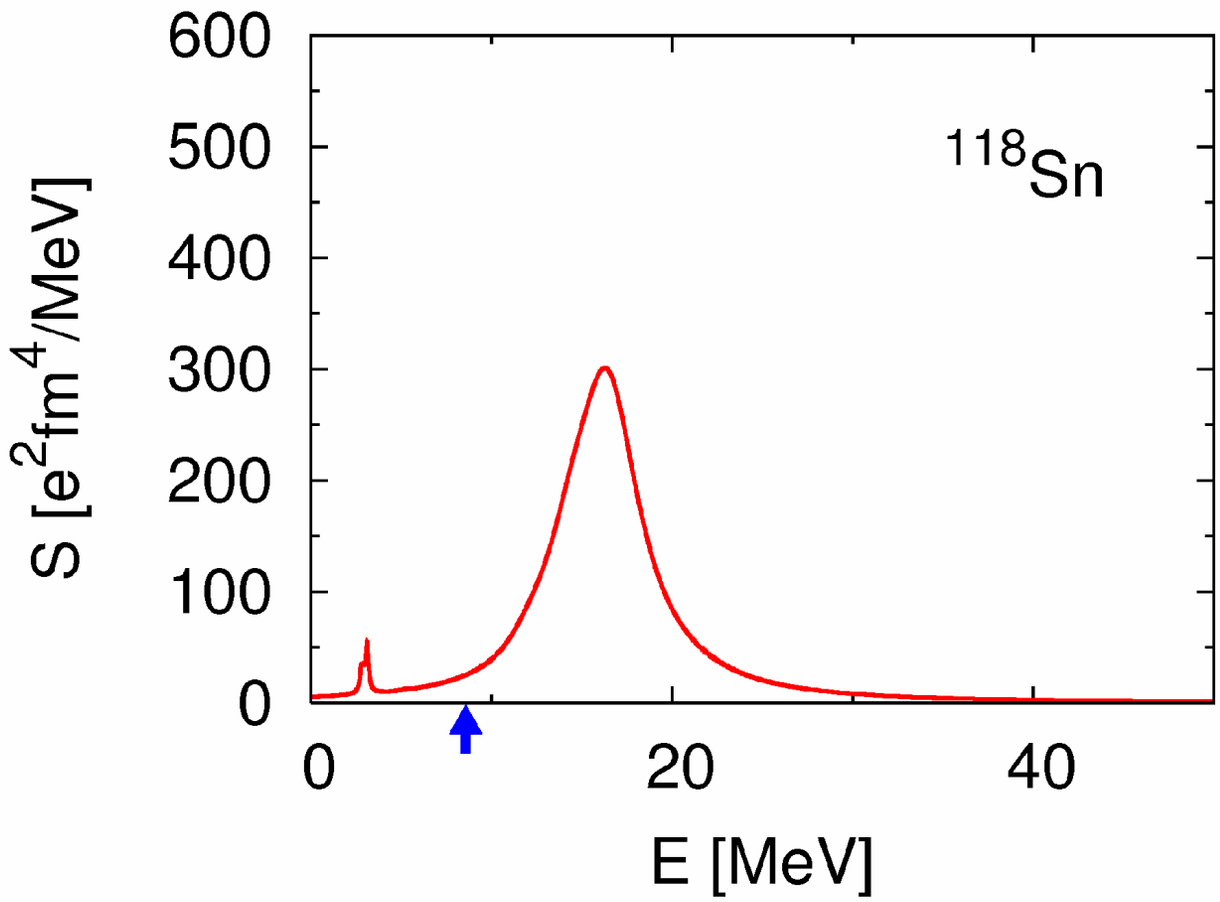


Isoscalar 0^+ strength functions



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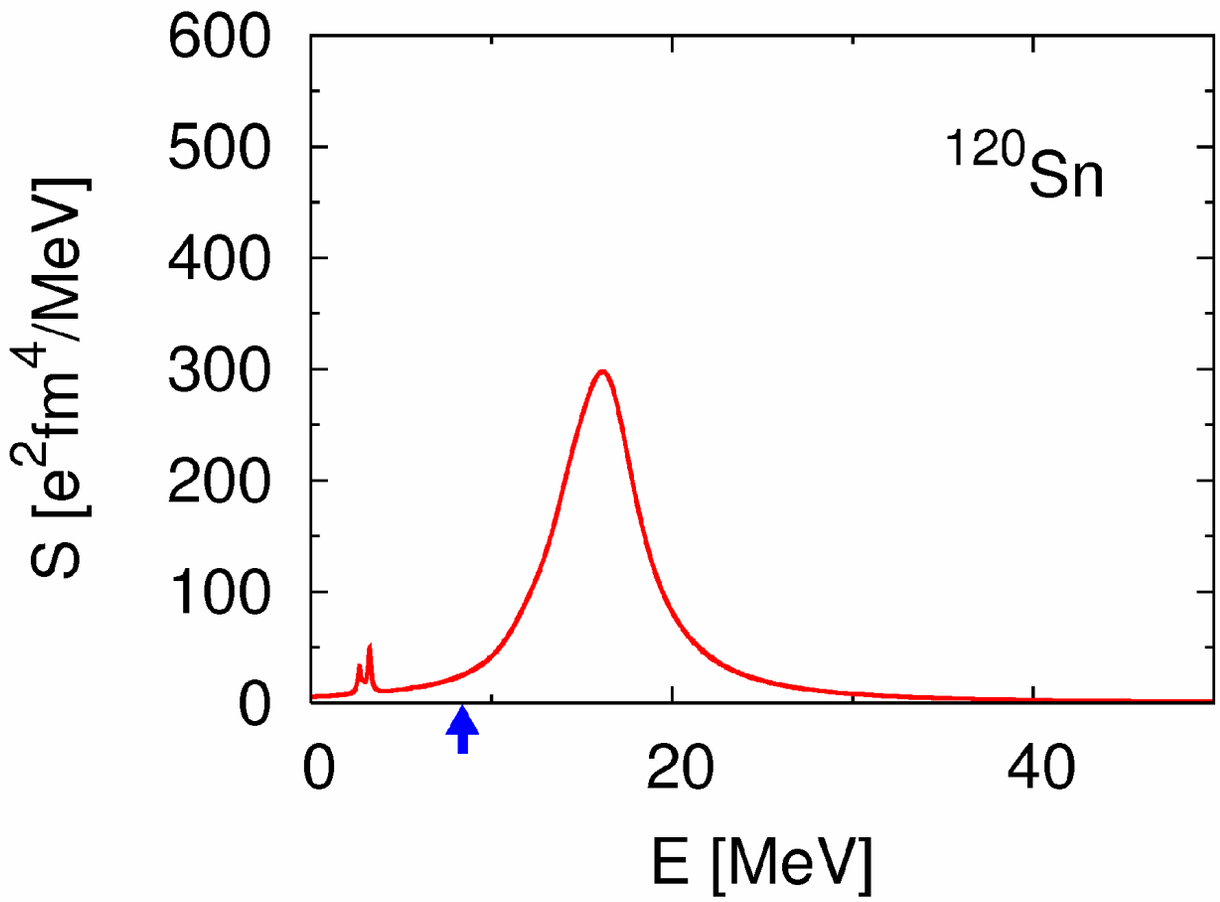

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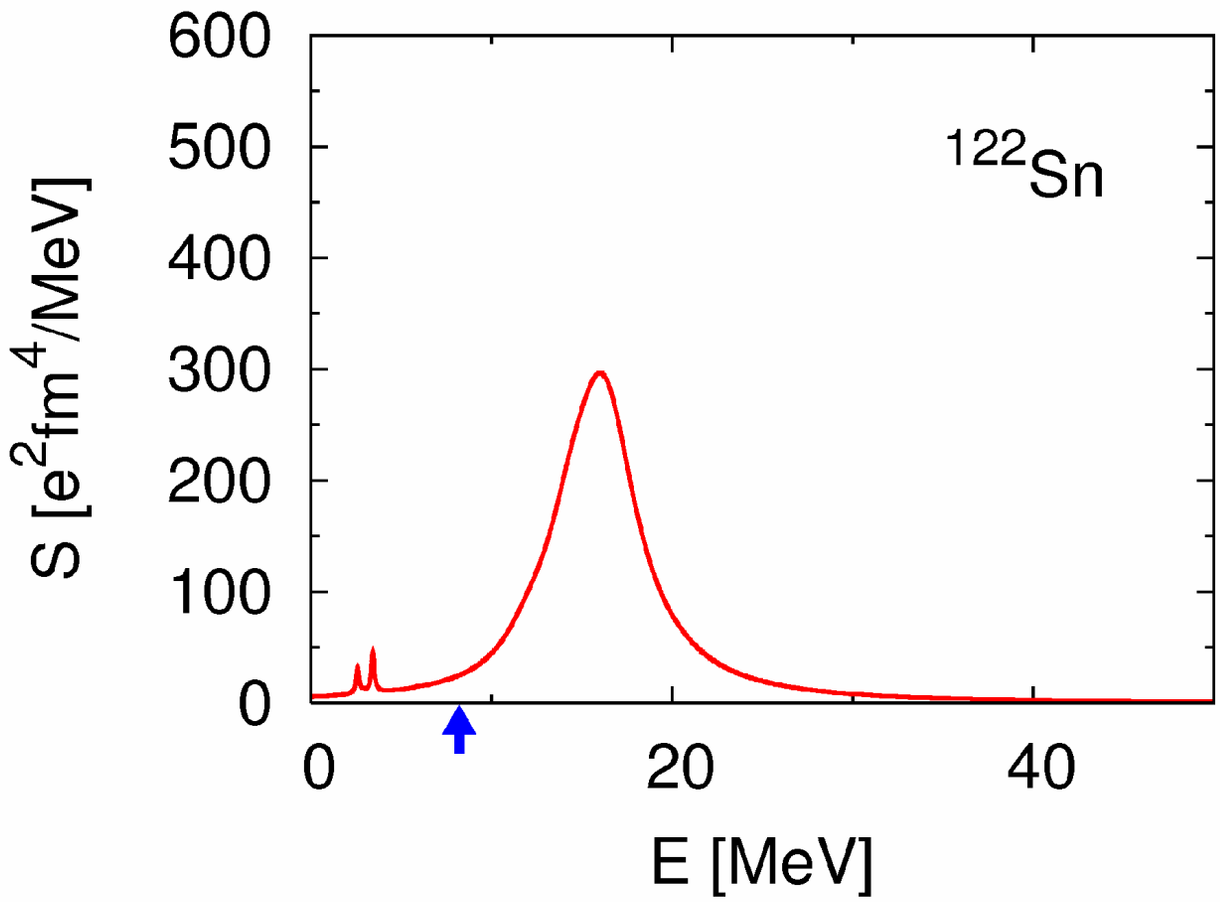

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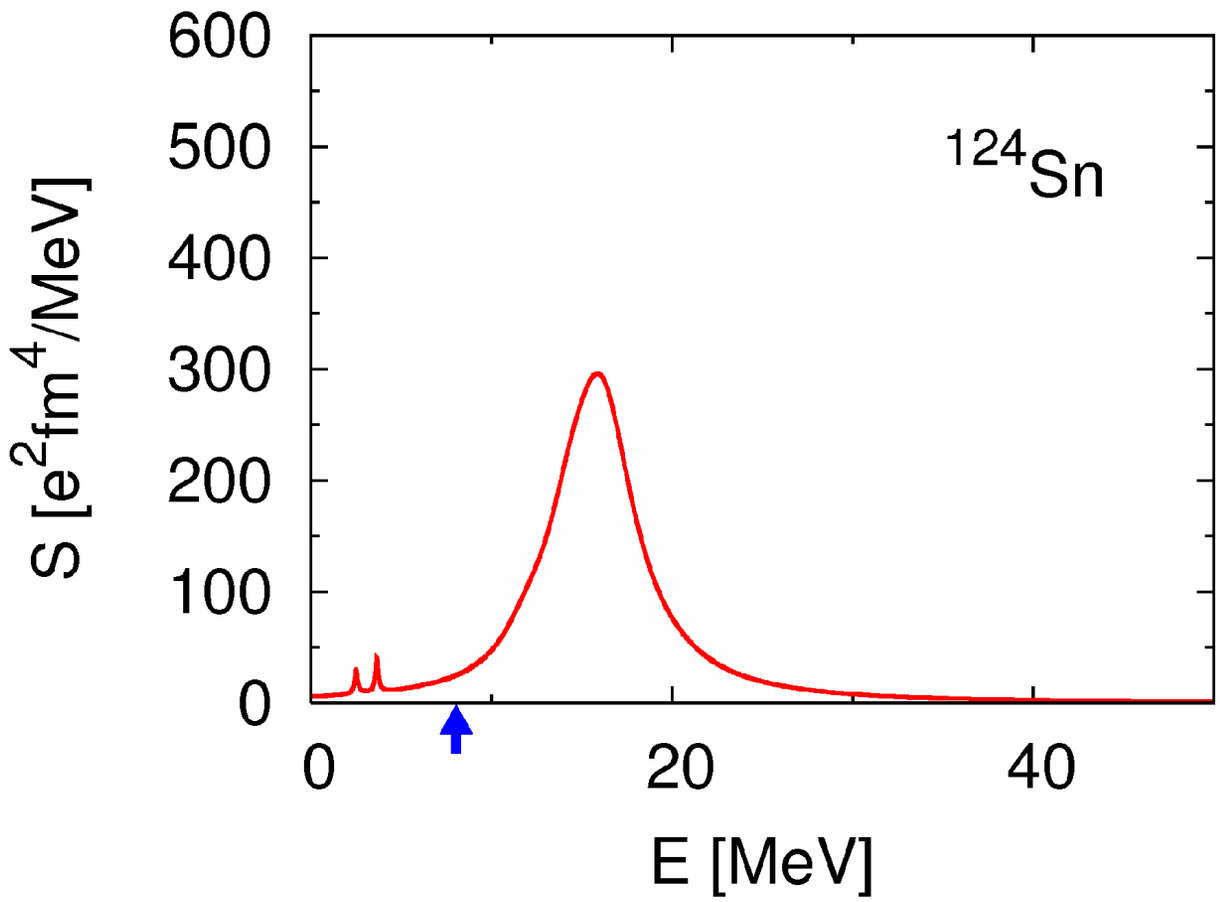

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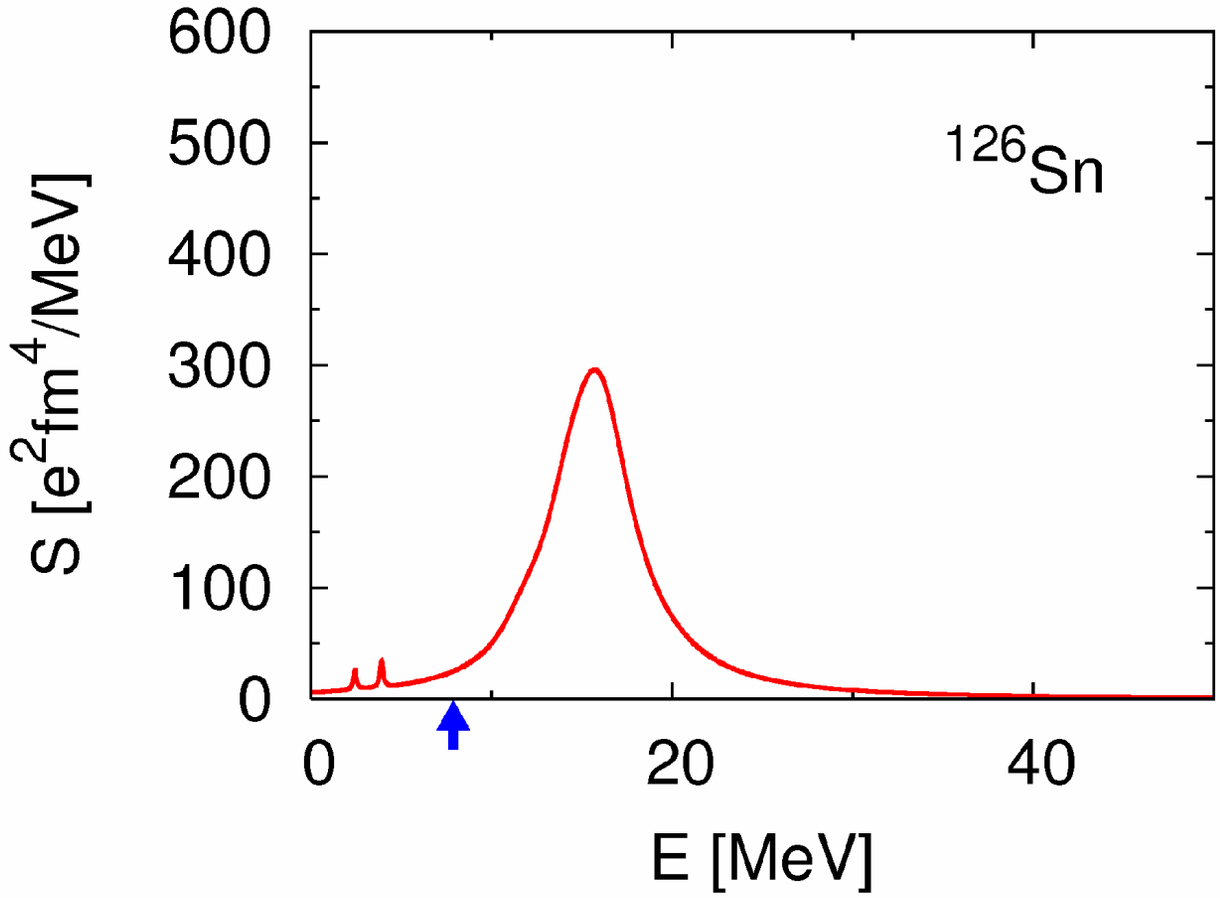

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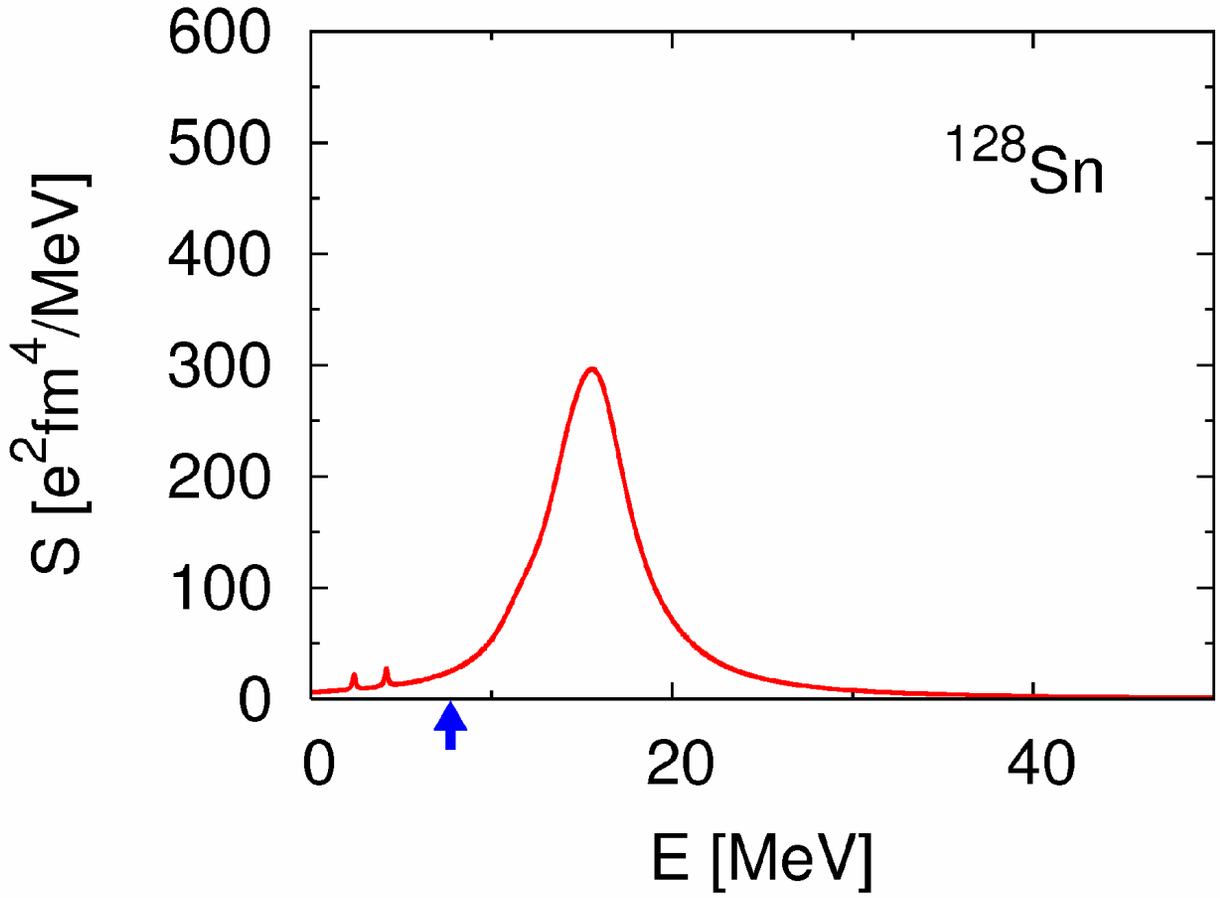

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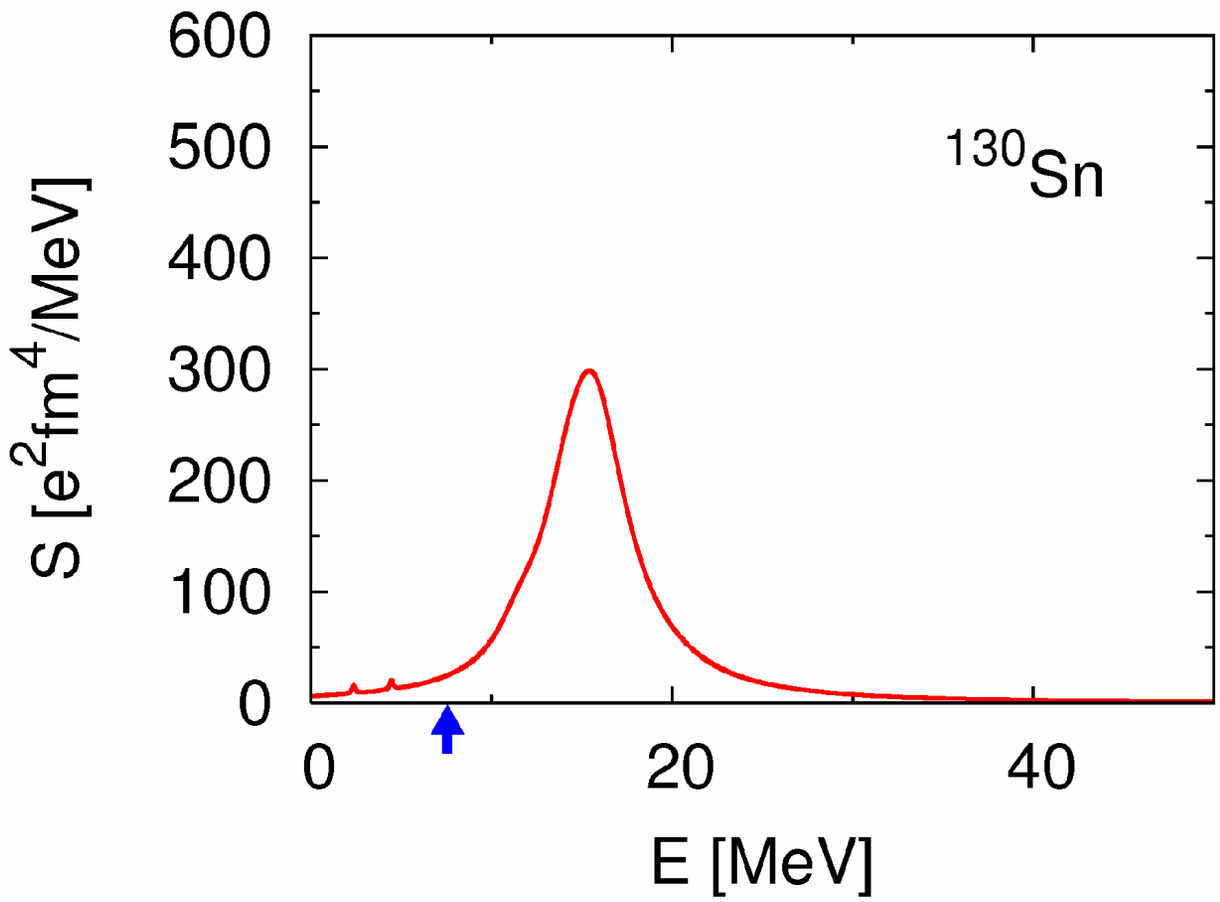

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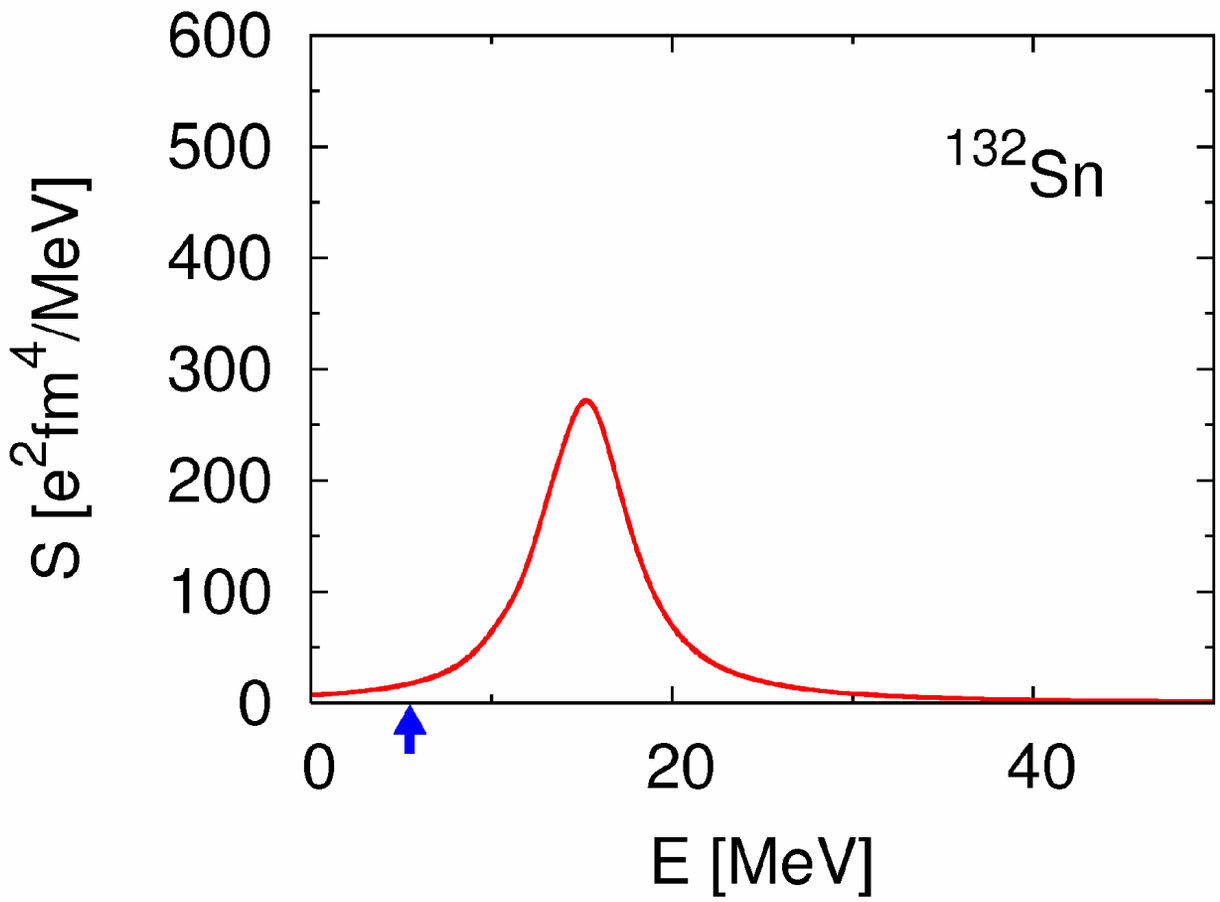

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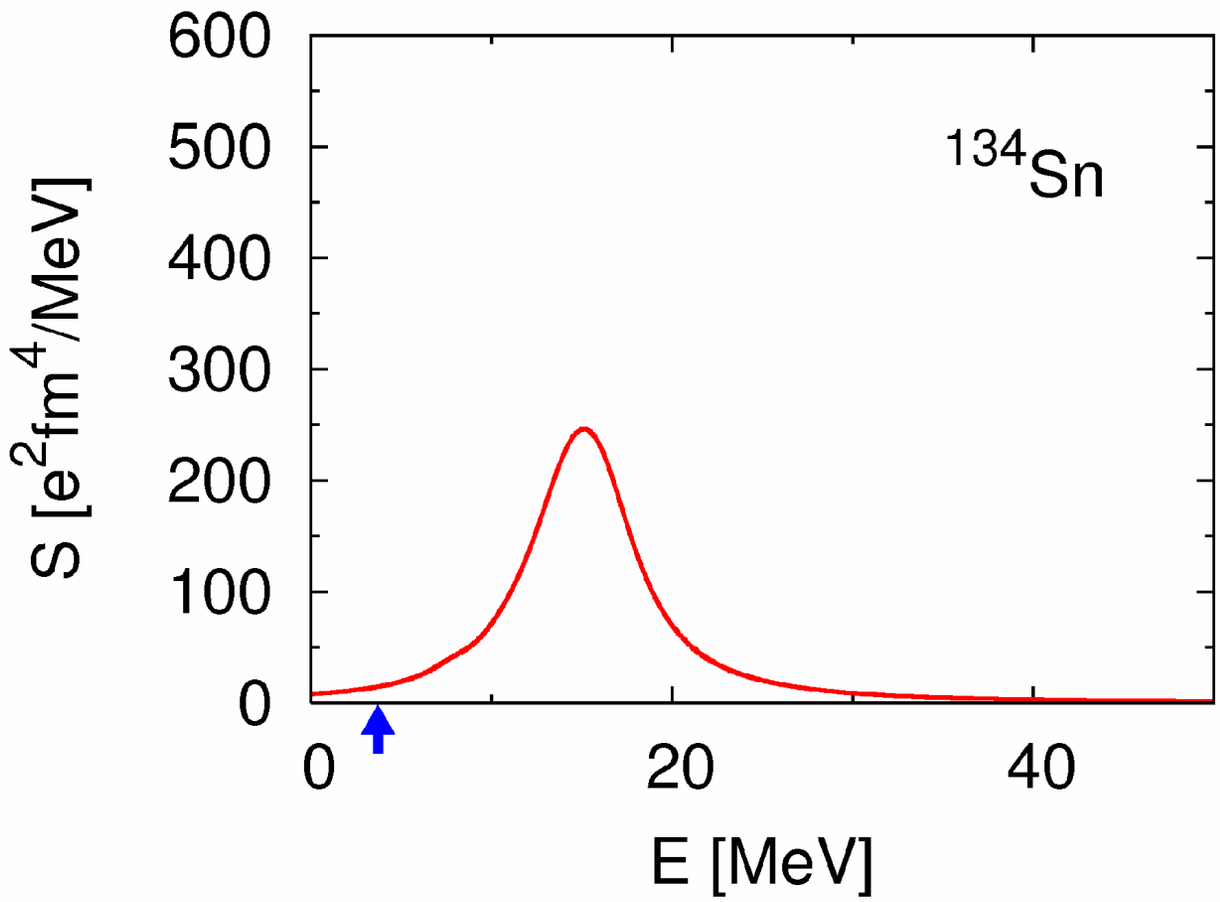

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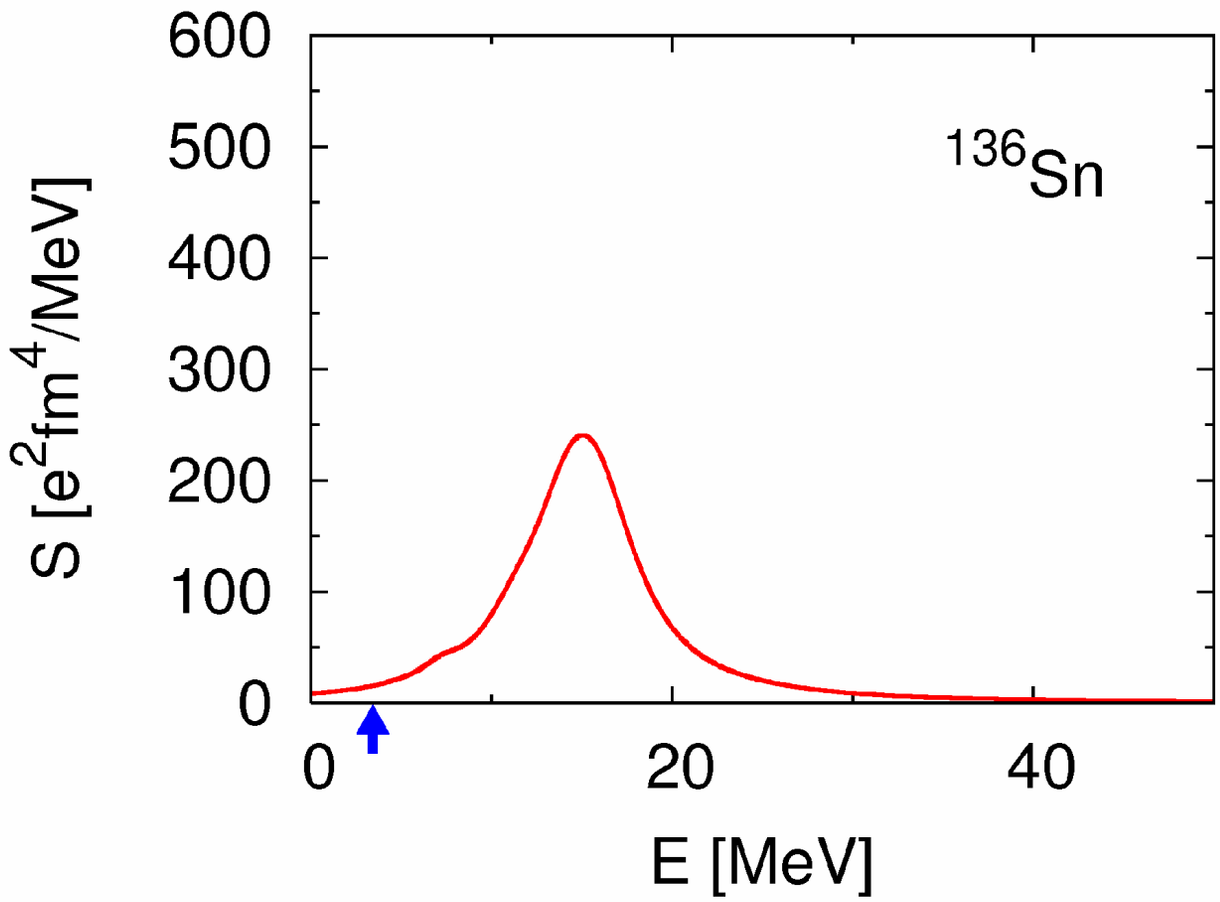

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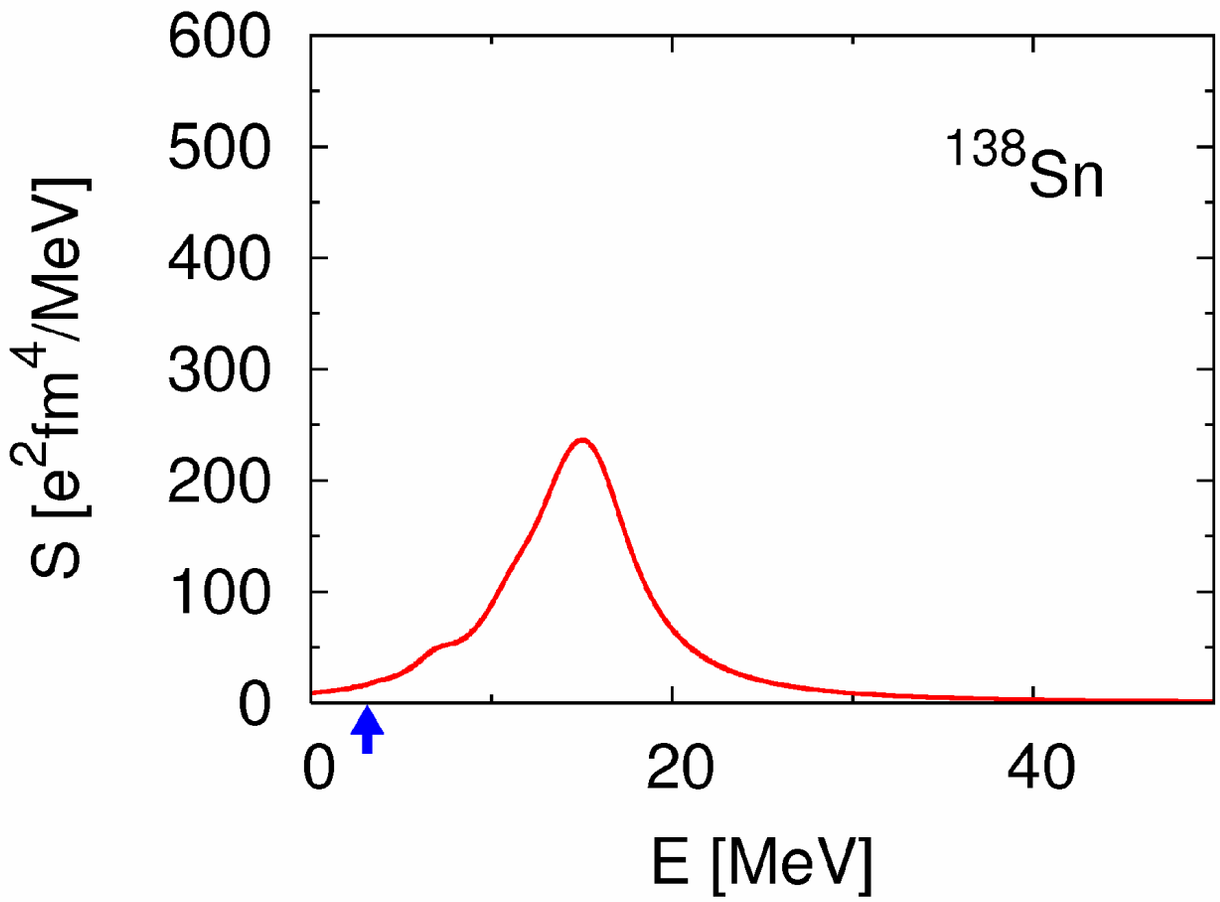

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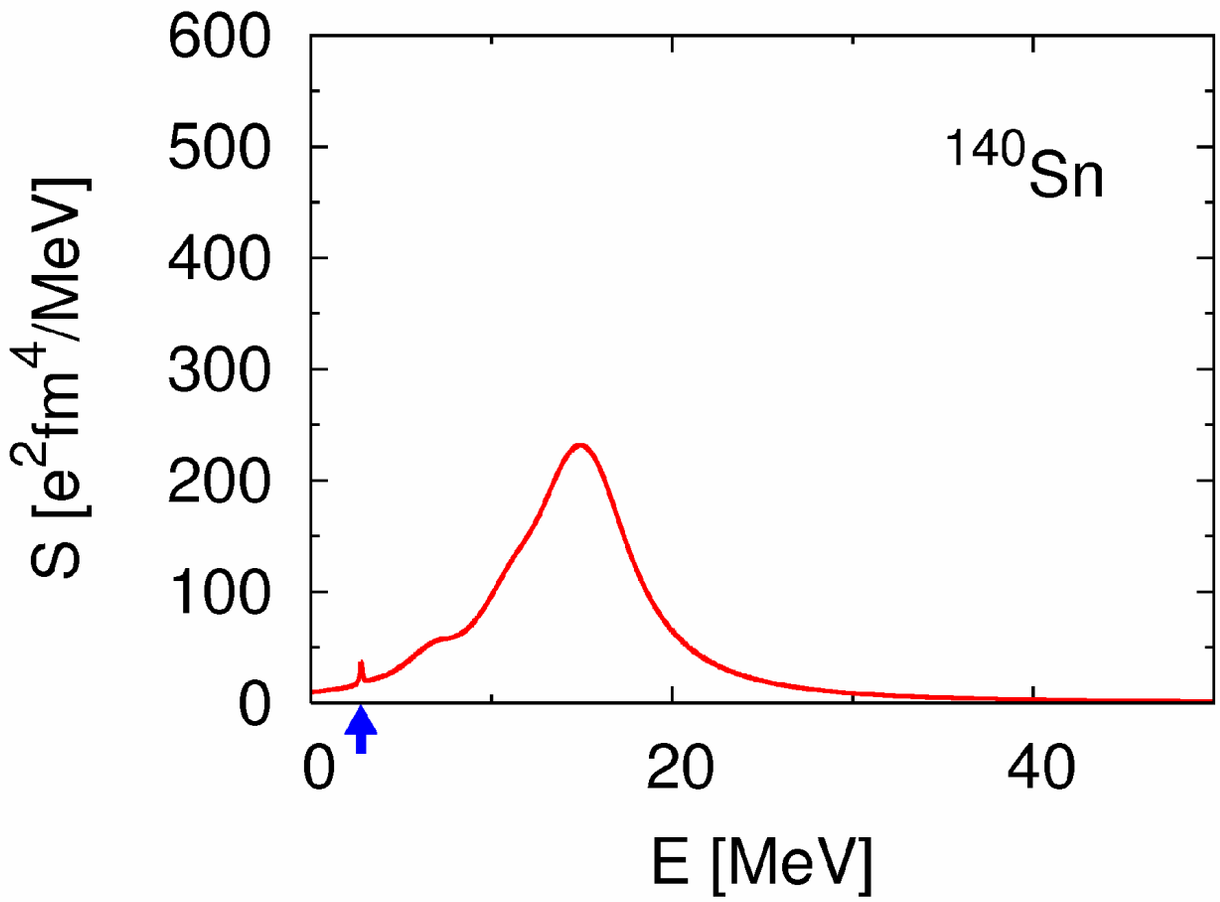
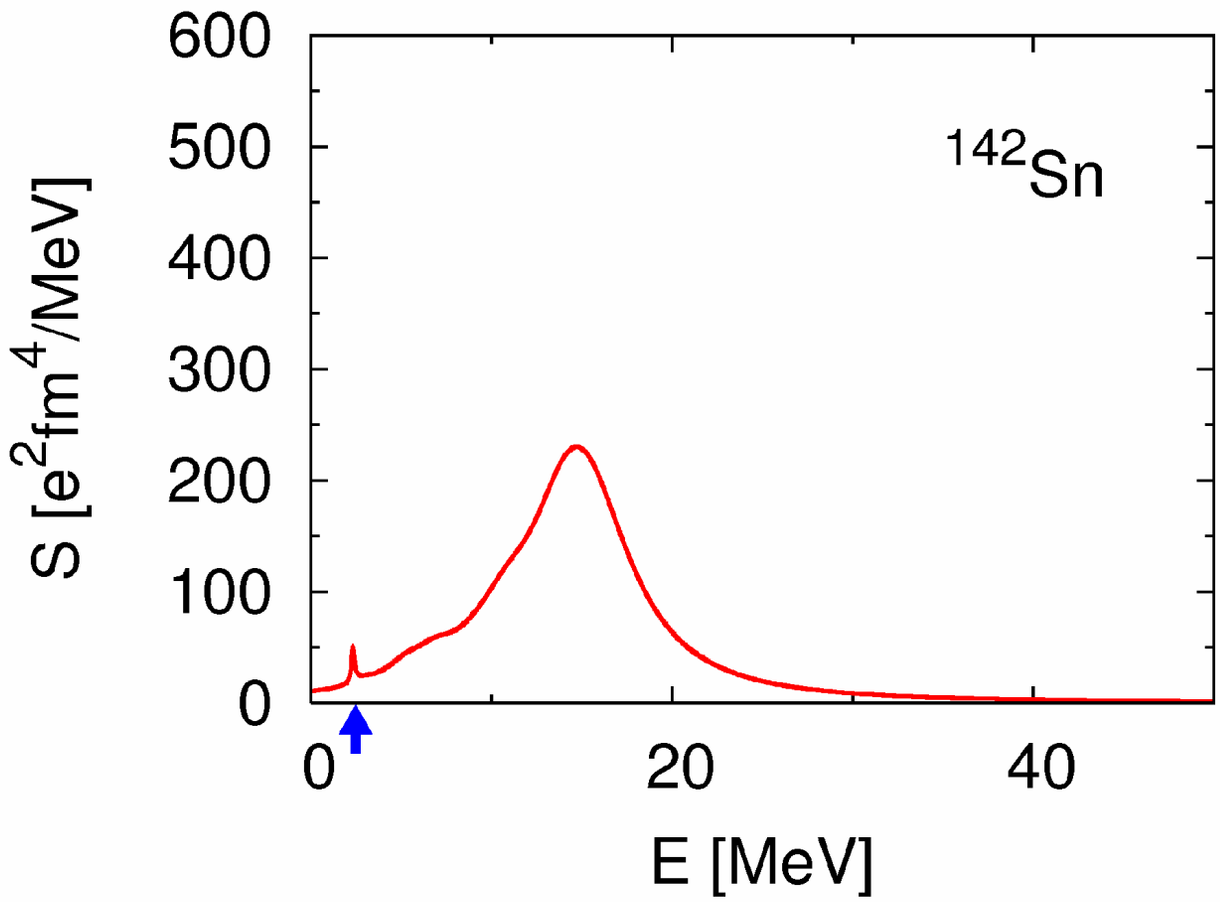
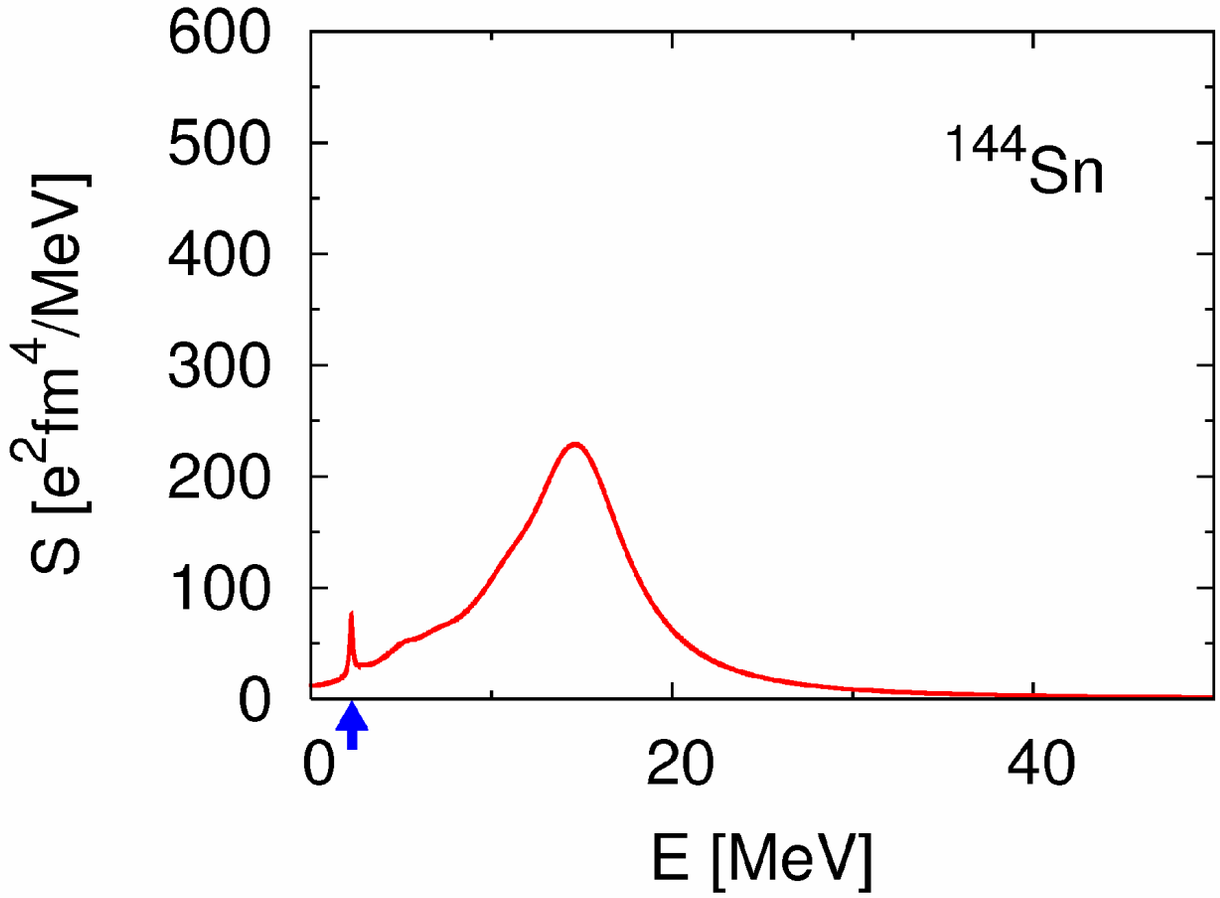


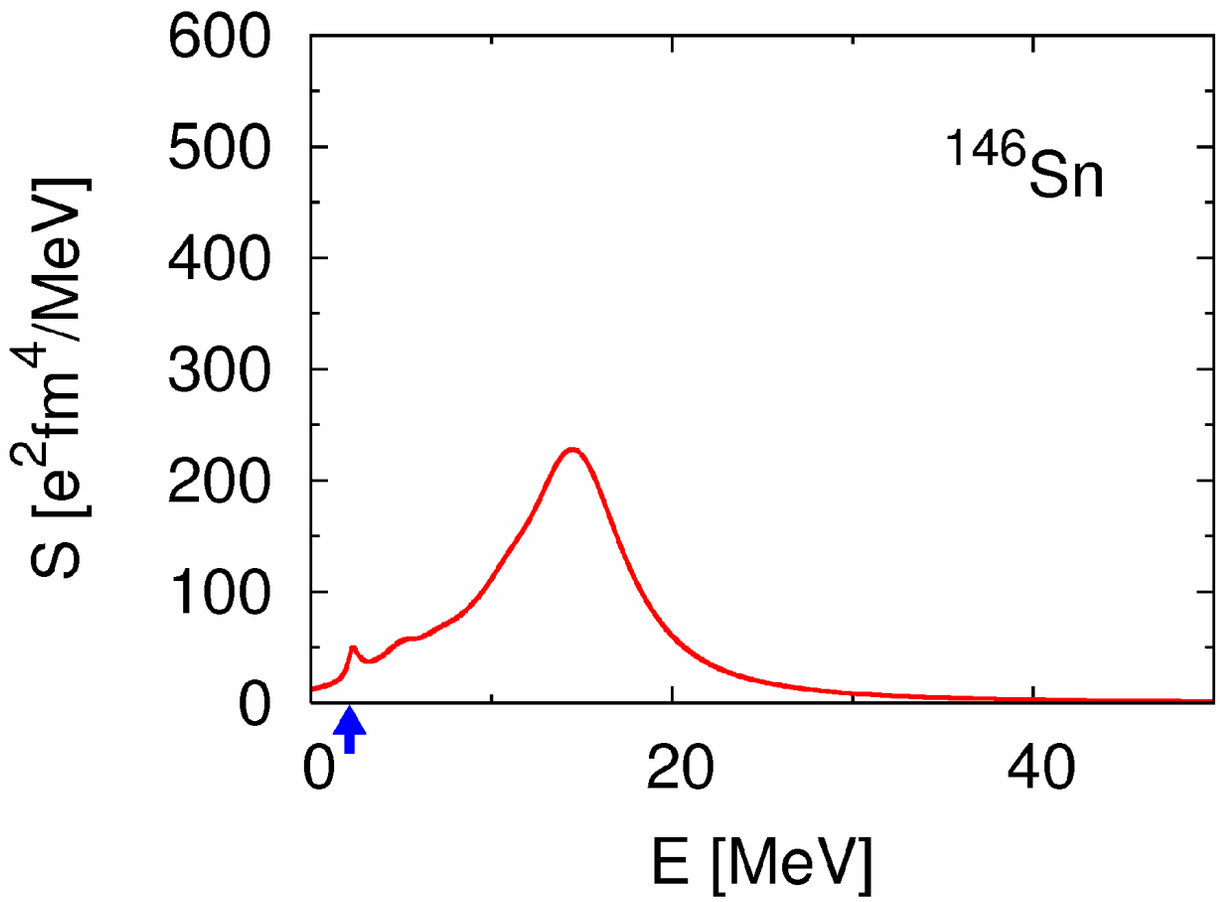
Isoscalar 0^+ strength functions



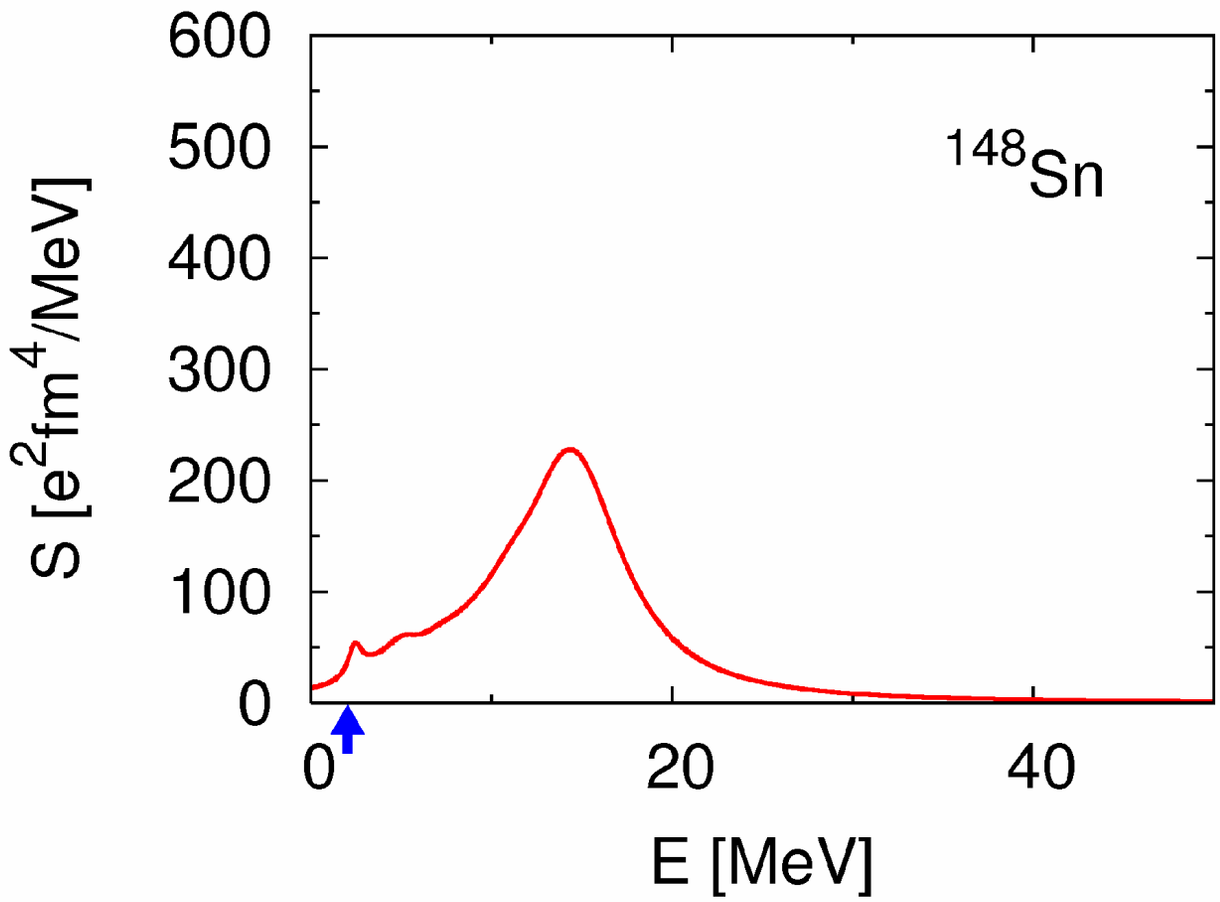
Isoscalar 0^+ strength functions



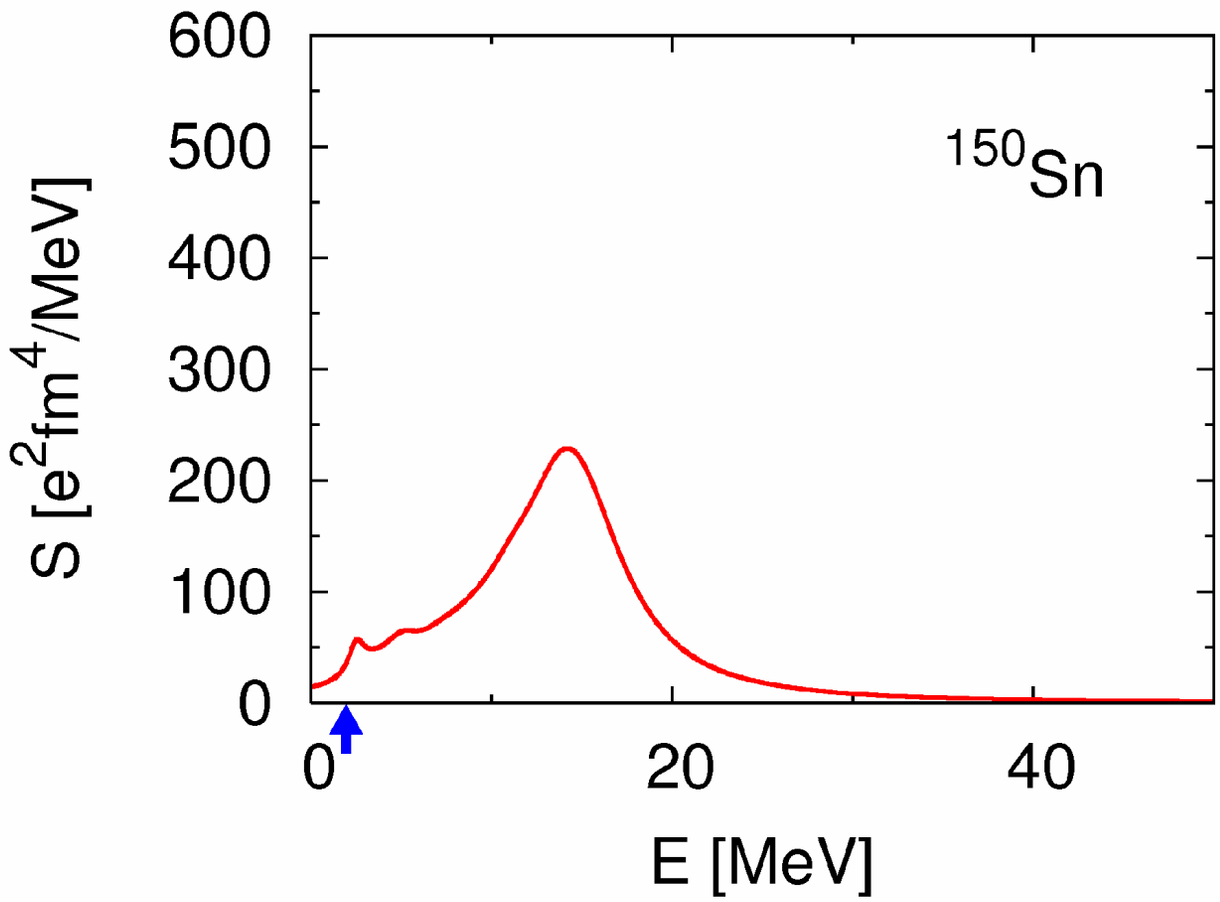
Isoscalar 0^+ strength functions



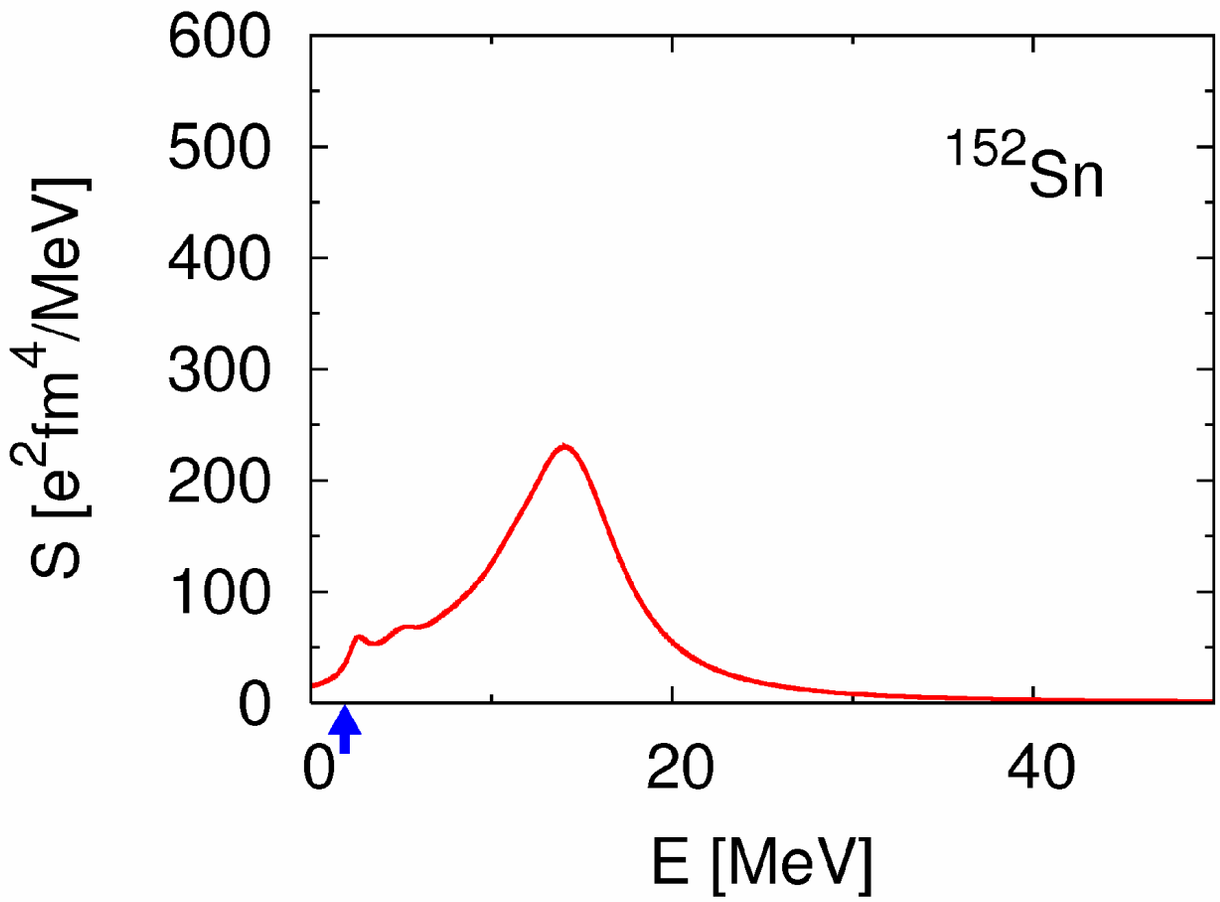
Isoscalar 0^+ strength functions



Isoscalar 0^+ strength functions

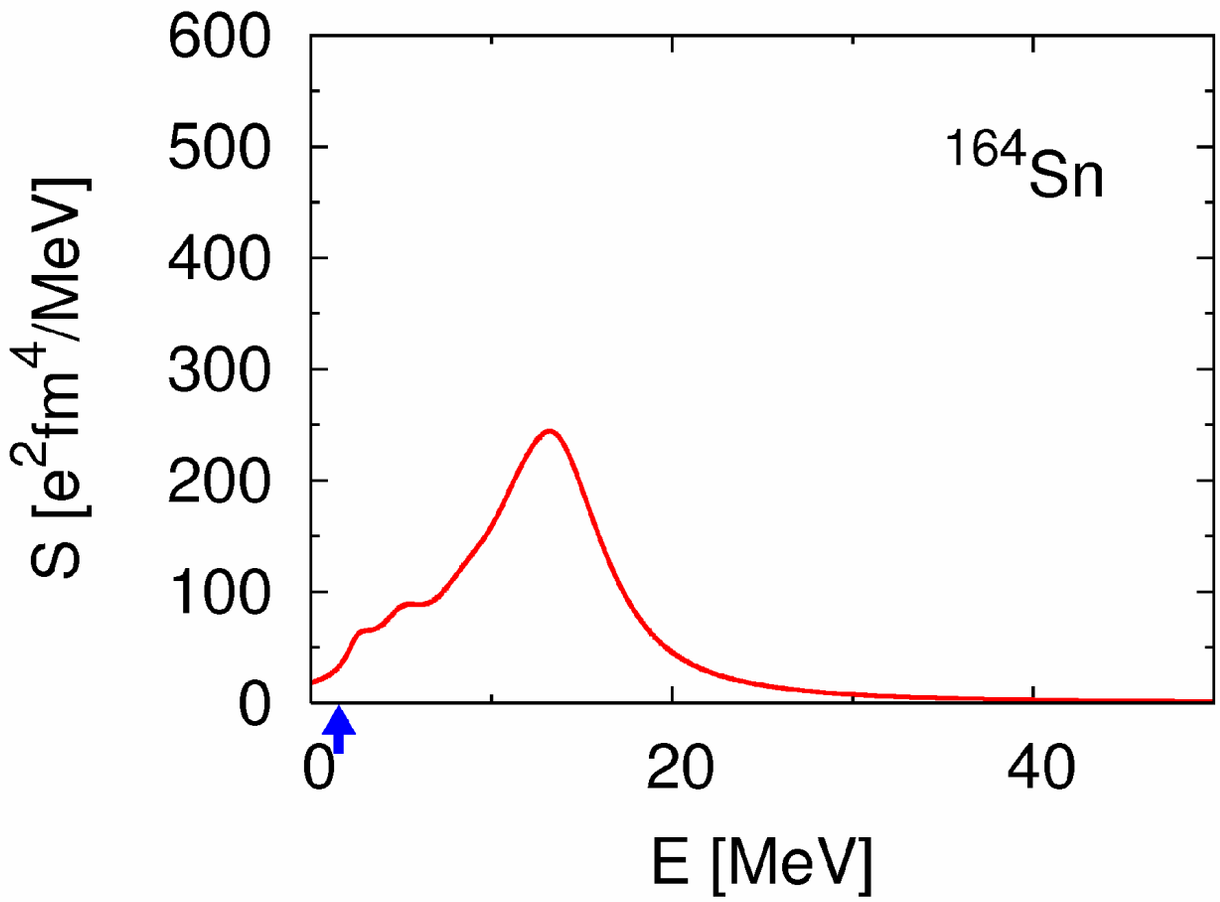


Isoscalar 0^+ strength functions

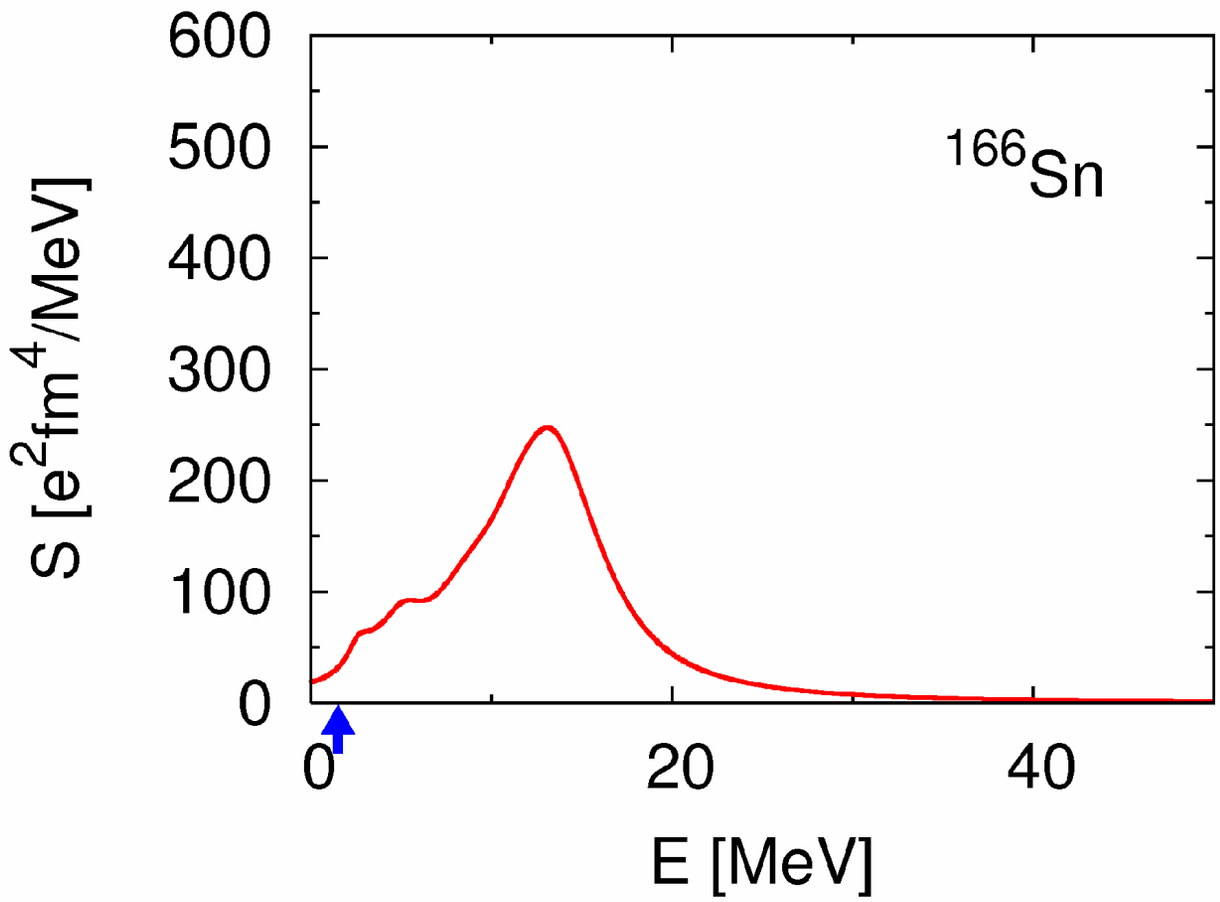


At A = 154 - 162 (N = 104 - 112)
ground states : deformed

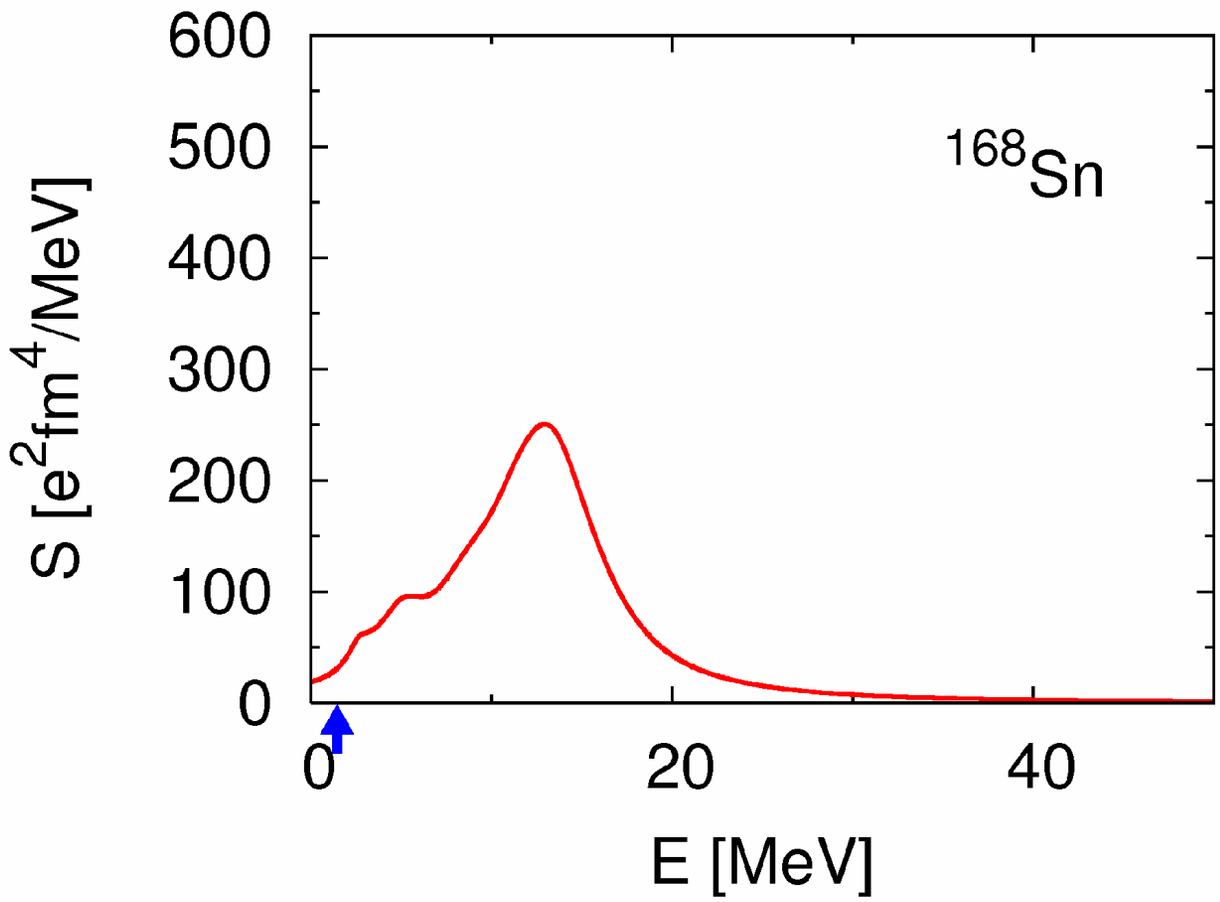
Isoscalar 0^+ strength functions



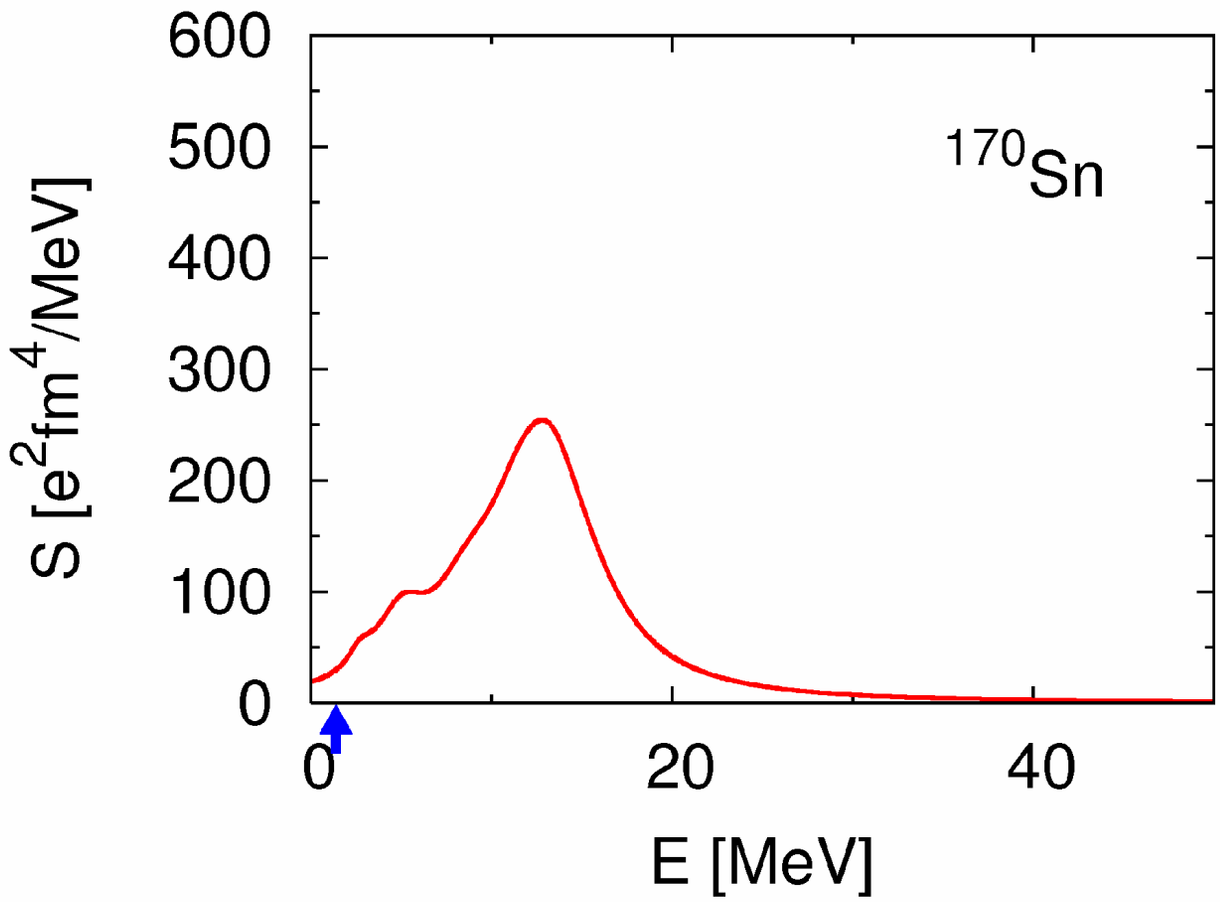
Isoscalar 0^+ strength functions



Isoscalar 0^+ strength functions



Isoscalar 0^+ strength functions



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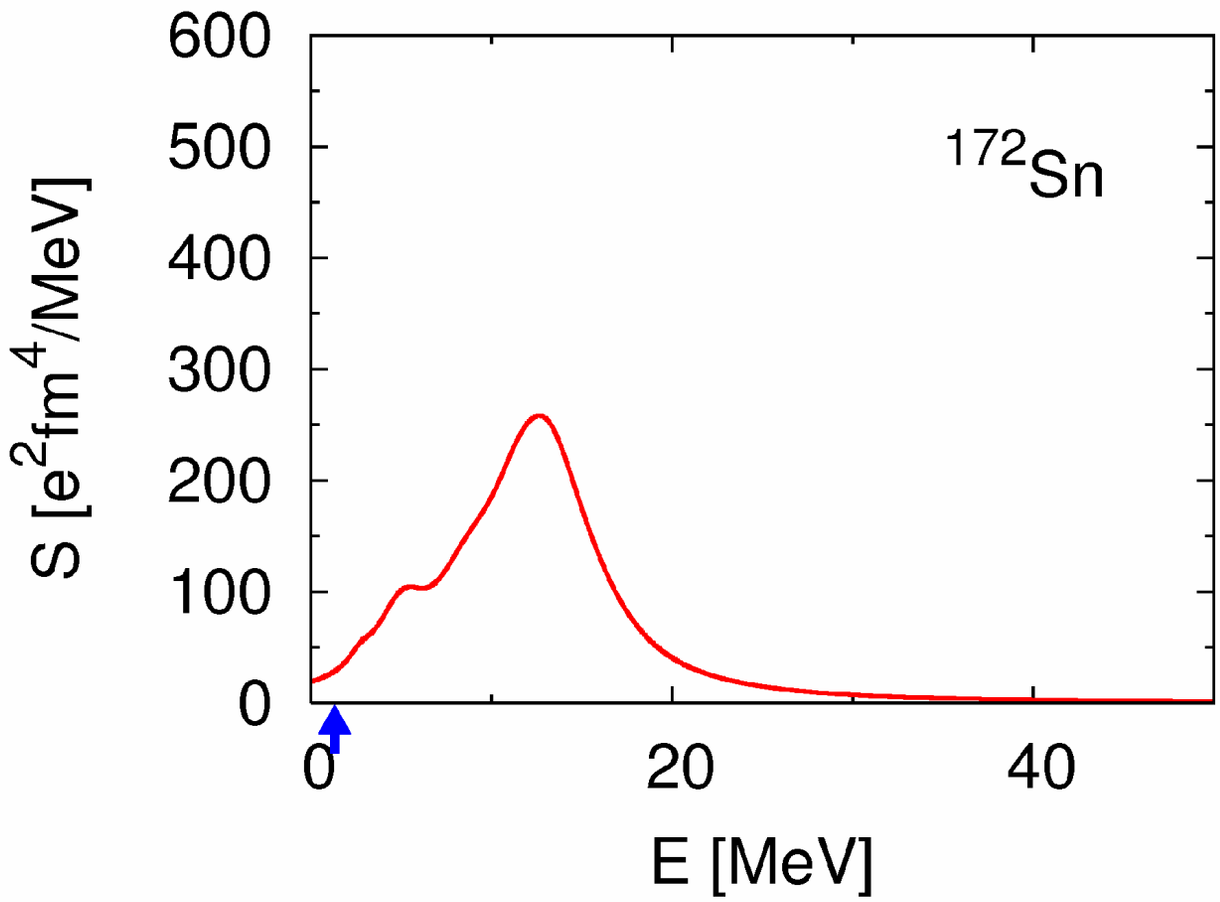

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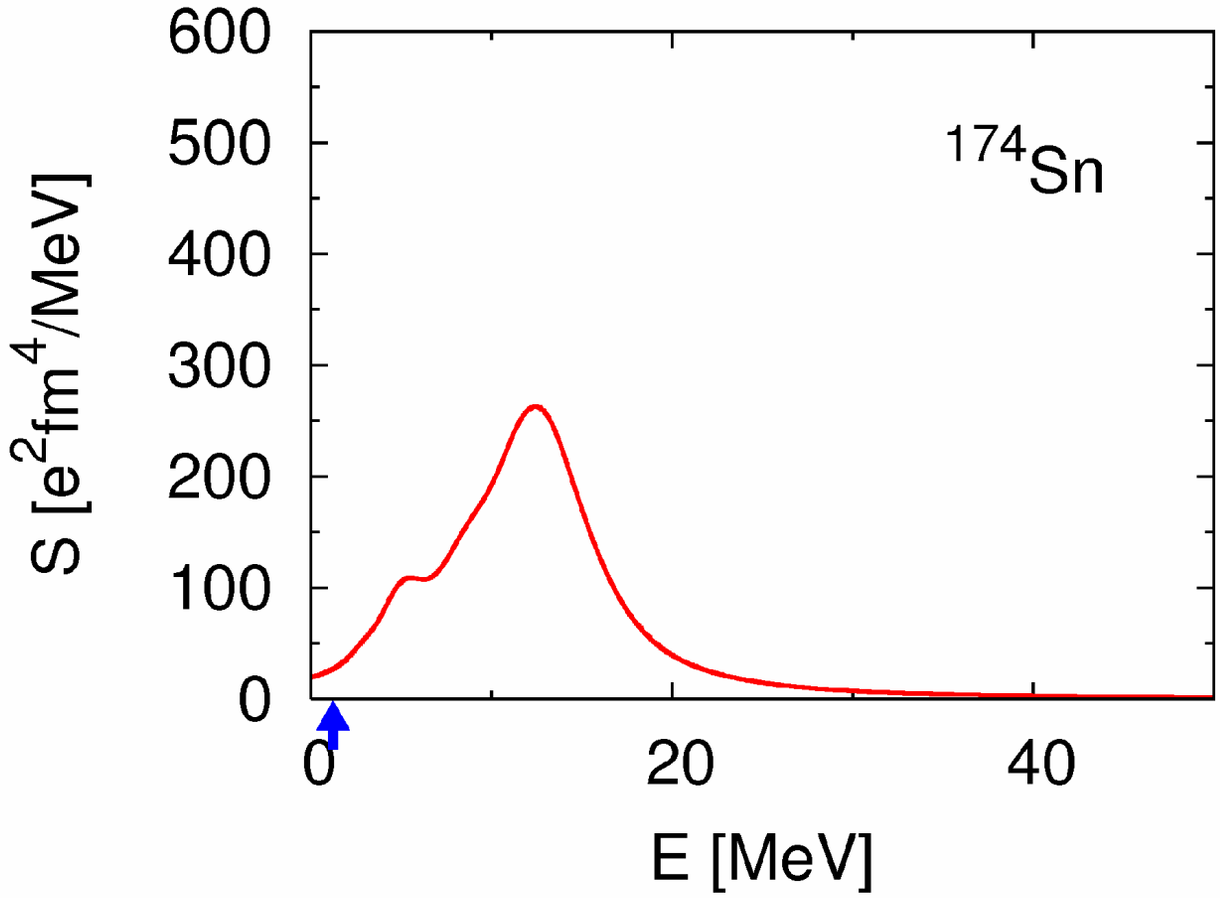
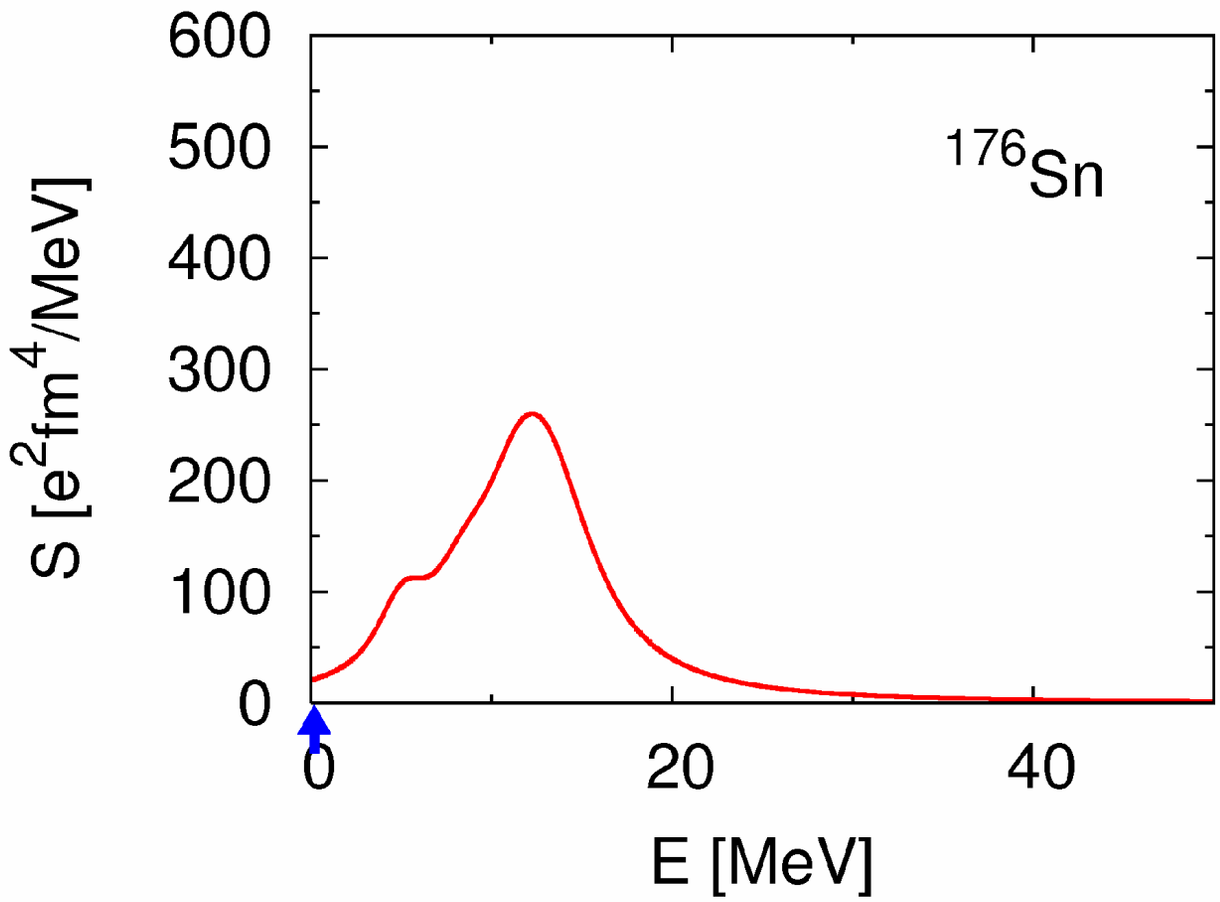


Isoscalar 0^+ strength functions



Exp. data

S.Shlomo and D.H. Youngblood, Phys.Rev.C, **47**, 529 (1993) Tab.**III**

However,

D.H. Youngblood et al., Phys.Rev.Lett., **82**, 691 (1999)

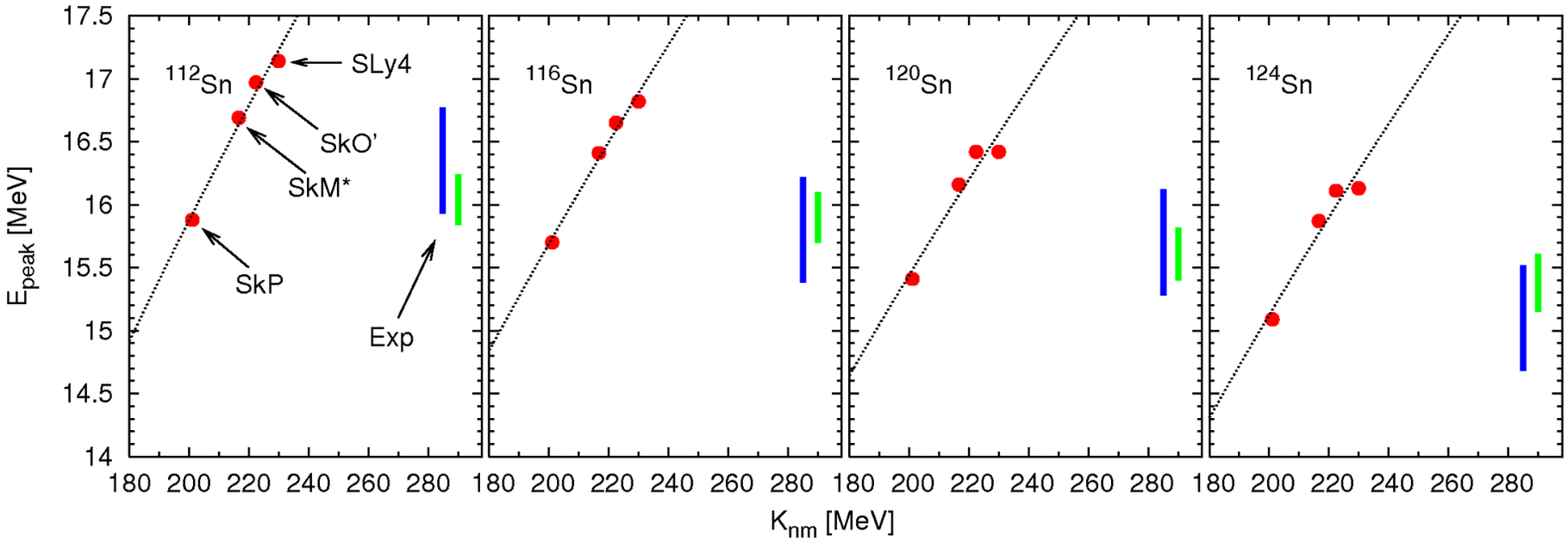
TABLE I. GMR energies and errors in MeV.

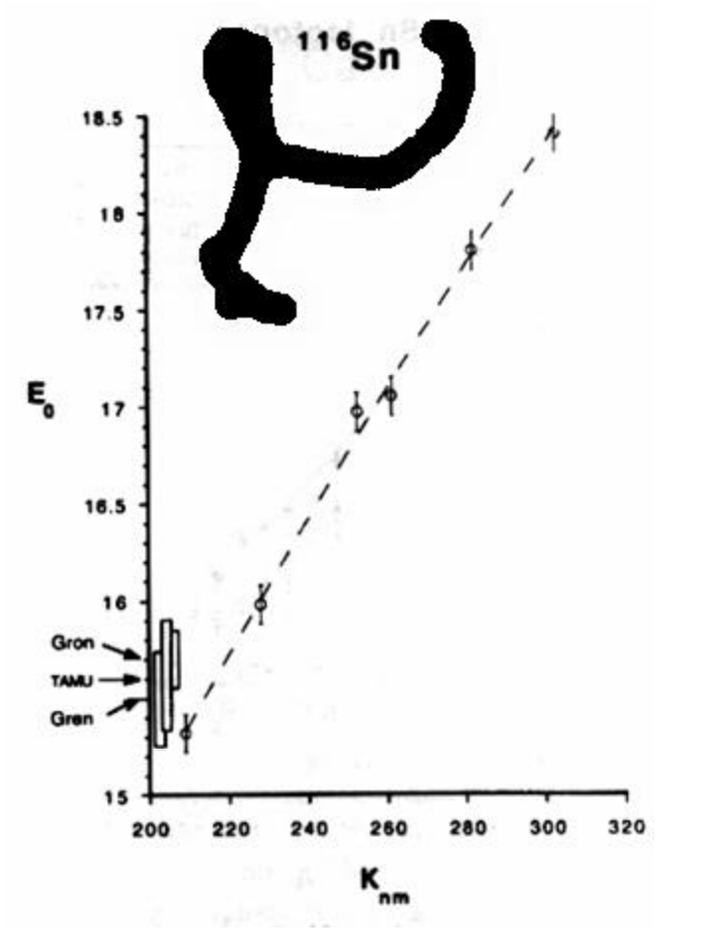
	TAMU 1998 Gaussian Cross Section		Previous Work Gaussian Cross Section		TAMU 1998 Gaussian $E0$ Strength	TAMU 1998 Slice Analysis $E0$ Strength	
	Centroid MeV	error MeV	Centroid MeV	error MeV	m_1/m_0 MeV	m_1/m_0 MeV	error MeV
^{90}Zr	16.44	0.07	16.10	0.28	16.80	17.89	0.20
^{116}Sn	15.77	0.07	15.60	0.16	16.00	16.07	0.12
^{144}Sm	15.16	0.11	15.10	0.14	15.31	15.39	0.28
^{208}Pb	13.91	0.11	13.90	0.30	14.24	14.17	0.28

15.50 0.20 in 1993

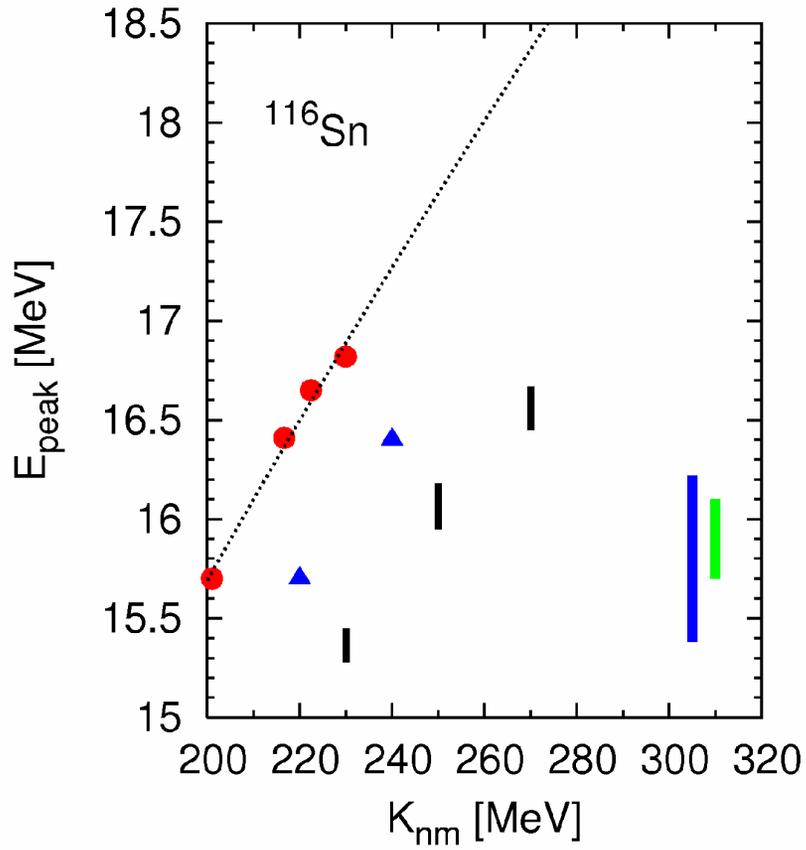
TAMU 1998 Adopted Energies $E0$ Strength	
$(m_1/m_{-1})^{1/2}$ MeV	error MeV
17.81	0.35
15.90	0.07
15.25	0.11
14.18	0.11

Peak energy of GMR and K_{nm}





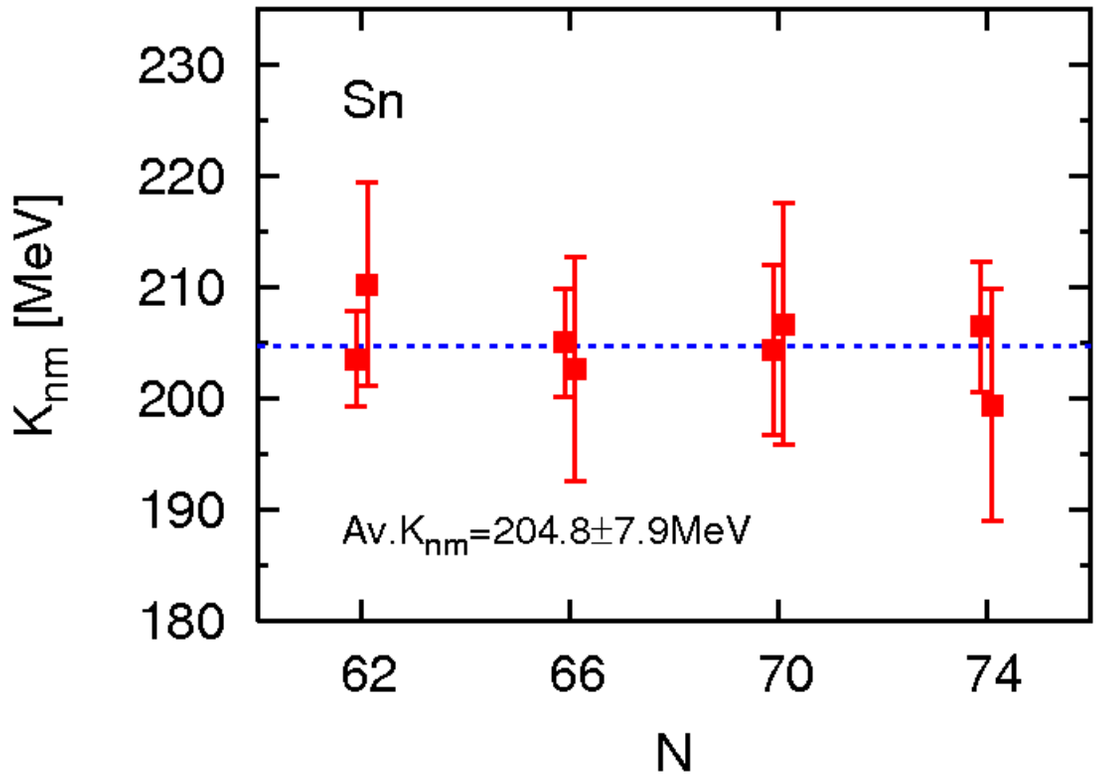
J.P. Blaizot et al., Nucl.Phys.A **591**, 435 (1995)



▲ M.Farine et al., Nucl.Phys.A **615** 135 (1997)

I D.Vretenar et al., P.R.C **68**, 024310 (2003)

K_{nm} obtained



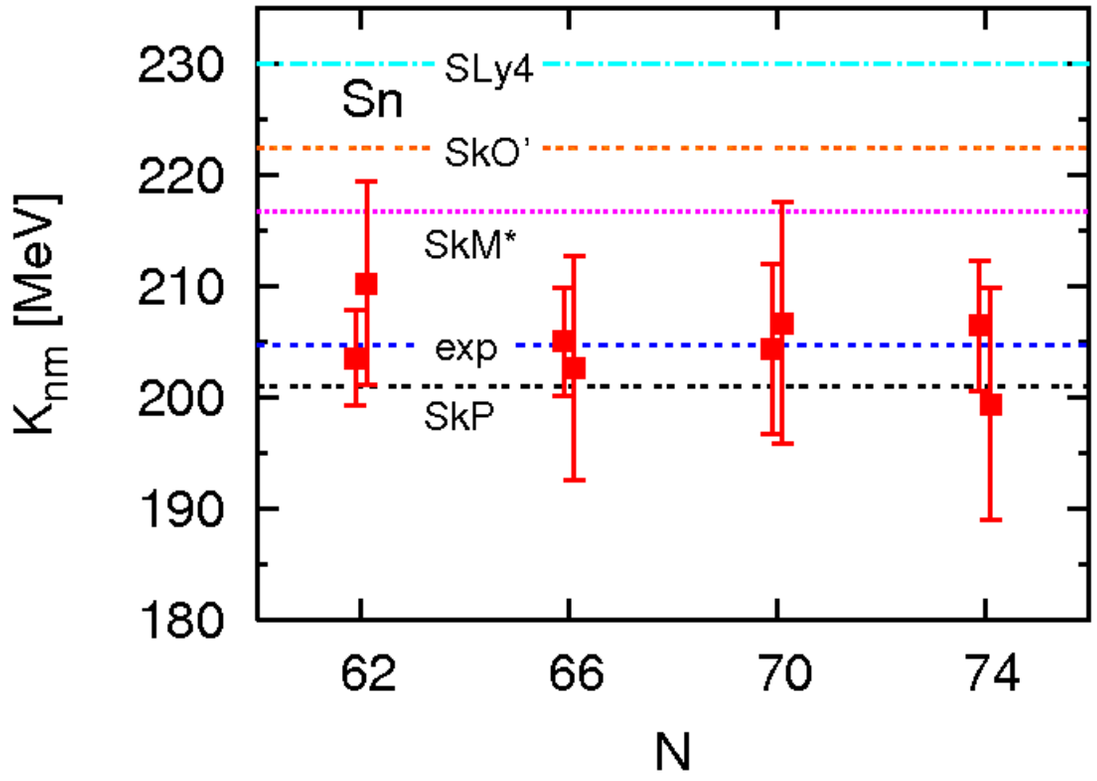
Blaizot et al., £ nm £ for ^{116}Sn

Farine et al., $K_V = 215 \pm 15$ MeV

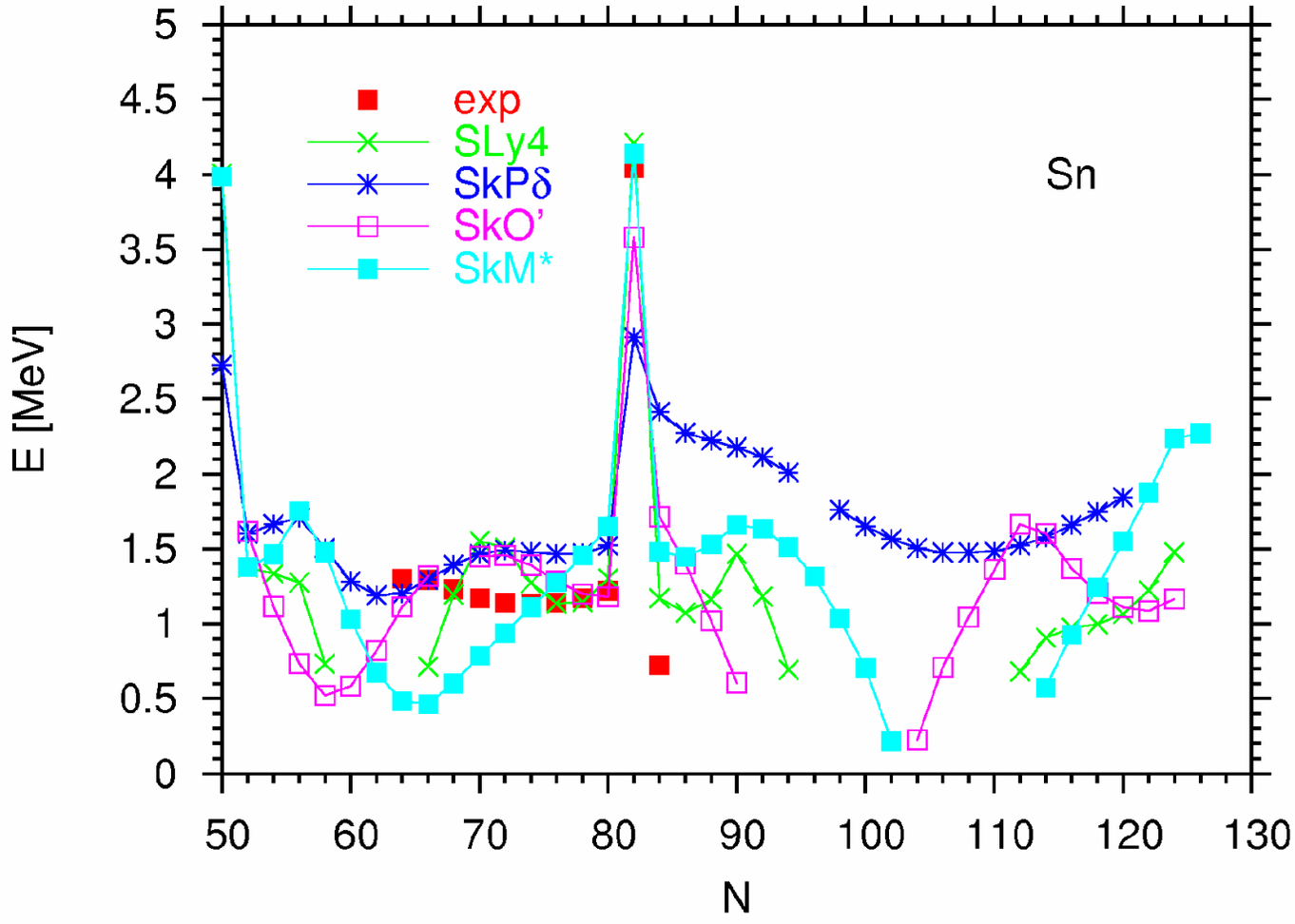
Colo` et al., "Bone fide Skyrme forces can either predict 230-240 MeV …"

Vretenar et al., K_{nm} » 250 - 270 MeV

K_{nm} obtained

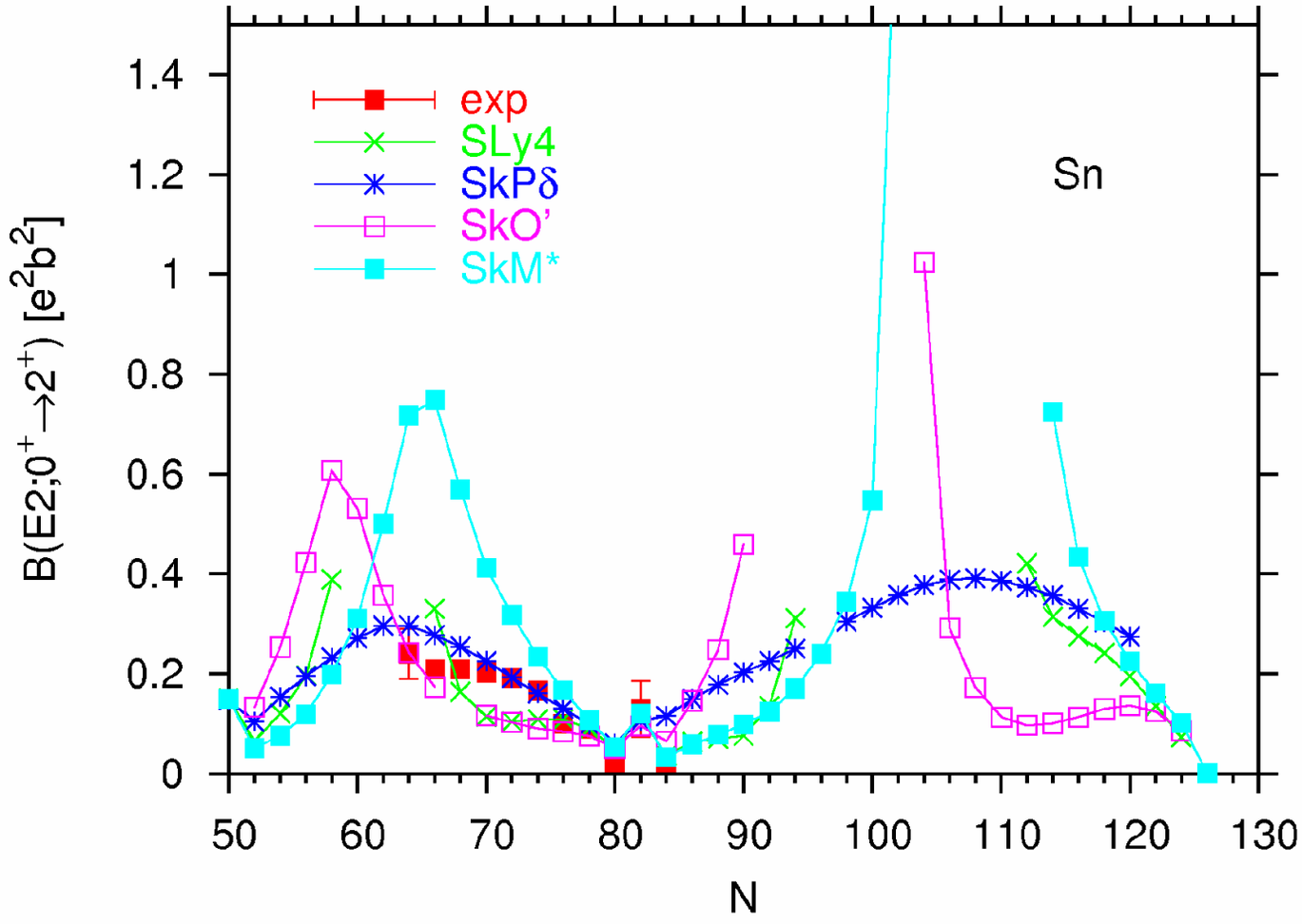


Energies of the lowest 2^+ states of Sn

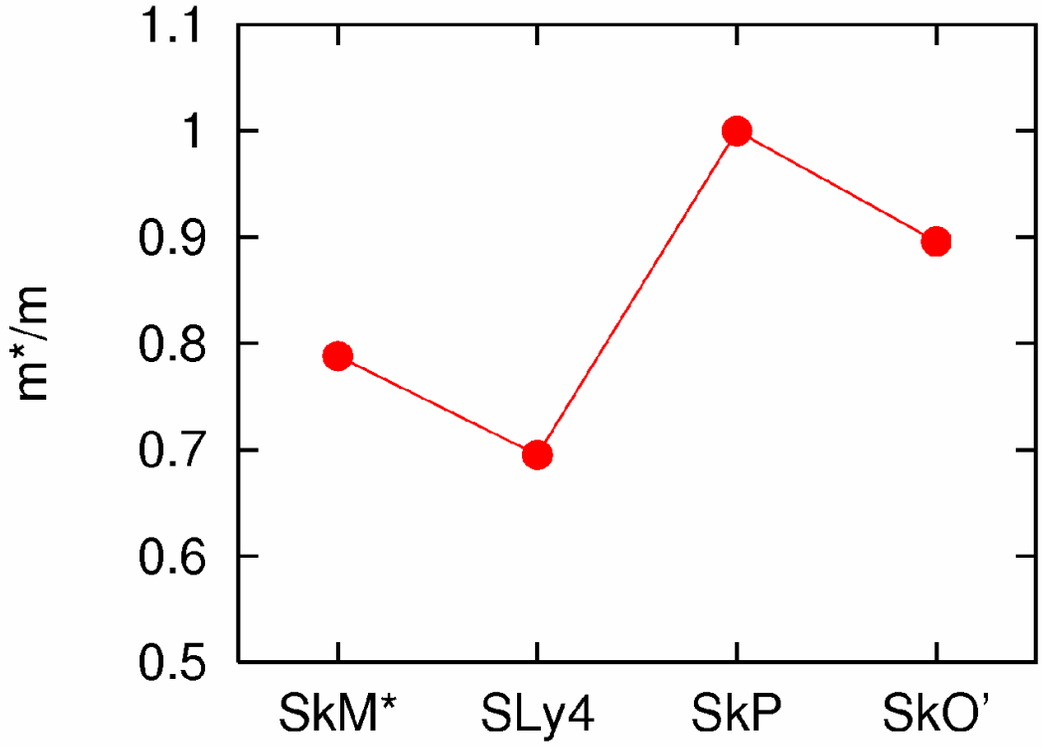


Exp.: S.Raman et al., Atom.Dat.Nucl.Dat.Tab. **78,** 1 (2001),
D.C.Radford et al., P.R.L. **88**, 222501 (2002); talk in ENAM04

Transition probabilities of the lowest 2^+ states of Sn



Effective mass (nuclear matter) / bare mass



Summary

- Systematic QRPA calculations have been done for even Sn, Ni, and Ca with $J^{\pi}=0^{+},1^{-}$, and 2^{+} from the proton drip line to the neutron drip line with a few parameter sets of the Skyrme interaction.

- Compression modulus was deduced from the experimental data of ^{112,116,120,124}Sn using the QRPA calculation;

  $K_{nm}=204.8 \pm 7.9$ MeV.

  SkP seems good.

I would like to thank

W. Nazarewicz, J. Engel, J. Dobaczewski, M. Bender, and M. Stoitsov

for their ***great*** helps to this research.