2022.10.18 Group meeting

Reading Phys. Rev. Lett. 129, 152501 (2022)

Quenching of Single-Particle Strength in A=15 Nuclei

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Three questions

What is the quenching?

How can we factorize the theoretical s.p. cross section?

What is the new discovery of this paper?

What is quenching?

$$R = \frac{\sigma_{exp}}{\sigma_{th}} < 1$$

σ_{exp}: Experimental cross section

σ_{th}: Theoretical prediction

$$\sigma_{th} = C^2 S \sigma_{sp}$$

sp: single particle state

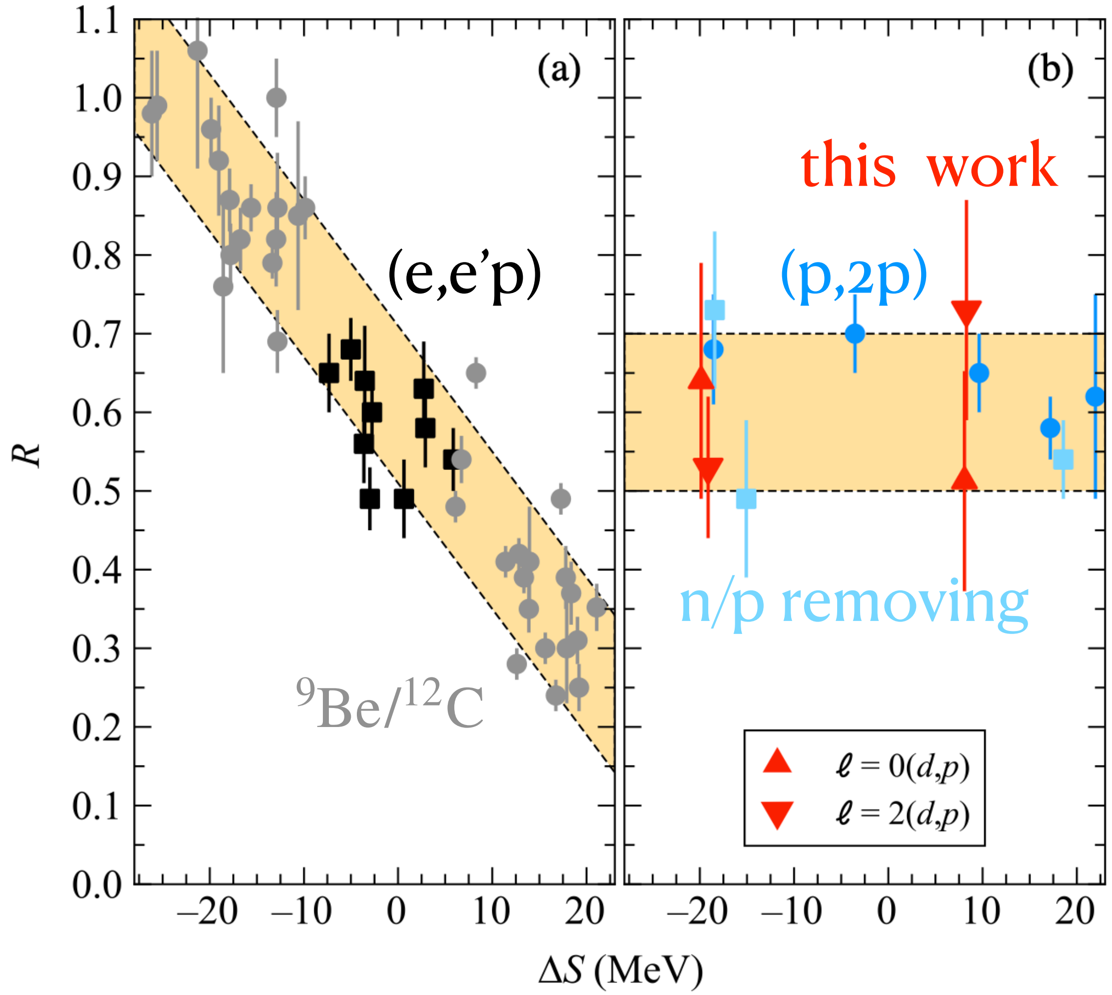
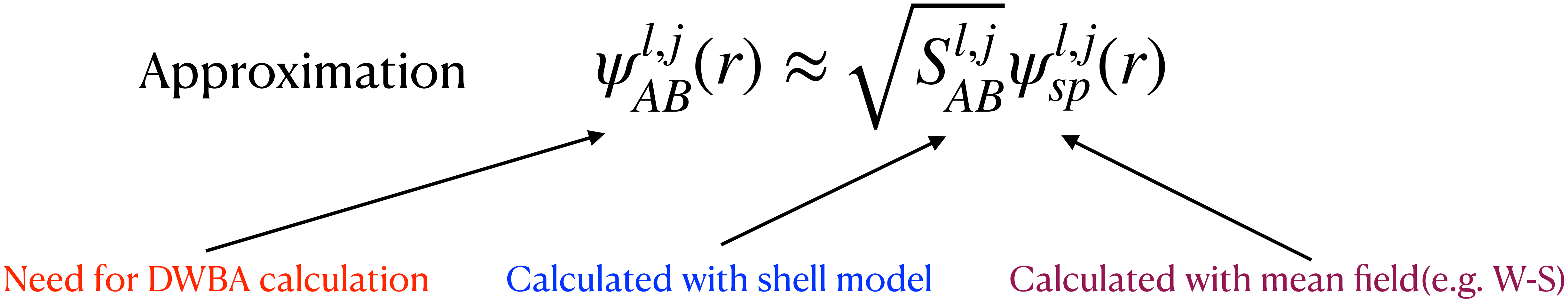


FIG. 1. (a) Degree of quenching R, as a function of ΔS deduced from $(e,e'p)$ reactions [3] (black squares) and from knockout reactions on ^{9}Be and ^{12}C targets (gray circles)—data and shaded band from Ref. [5], compared with (b) results from the current measurement (red triangles) and previous neutron- and proton-removing transfer reaction study of Ref. [7] (blue squares) and the $(p,2p)$ study [8] (blue circles). The shaded band, $R = 0.6(1)$, in (b) is to guide the eye. The $(e,e'p)$ and $(p,2p)$ measurements are compared to the independent single-particle model and the rest, including the present Letter, to the shell model.

Theoretical prediction

Overlap integration
$$\psi_{AB}^{l,j}(r) = \int d\xi \; \Psi_B^*(\xi, r)\Psi_A(\xi)$$

Spectroscopic factor
$$\int d^3r \,|\,\psi_{AB}^{l,j}(r)\,|^2 = S_{AB}^{l,j}$$



Approximation
$$\psi_{AB}^{l,j}(r) \approx \sqrt{S_{AB}^{l,j}}\psi_{sp}^{l,j}(r)$$

Need for DWBA calculation

Calculated with shell model

Calculated with mean field(e.g. W-S)

[1] T. Aumann, C. Barbieri, D. Bazin, C. A. Bertulani, A. Bonaccorso, W. H. Dickhoff, A. Gade, M. Gómez-Ramos, B. P. Kay, A. M. Moro et al., Quenching of single-particle strength from direct reactions with stable and rare-isotope beams, Prog. Part. Nucl. Phys. 118, 103847 (2021).

Theoretical prediction

$$\frac{d\sigma(\theta)}{d\Omega} = gC^2S_i \left.\frac{d\sigma(\theta)}{d\Omega}\right|_{sp}$$

Statistical factor   Isospin coefficient   SF   s.p. cross section

$$g = \begin{cases} 2j+1 & \text{when adding} \\ 1 & \text{when removing} \end{cases}$$

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Sum rule

Total degeneracy $n_{vac} + n_{occ} = 2j + 1$

For adding and removing data

$$(2j+1)N_j = \sum (2j+1)C^2S_j^+ + \sum C^2S_j^-$$

For only adding/removing data

$$N_j = \frac{1}{2j+1}\sum (2j+1)gC^2S_j$$

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Some results

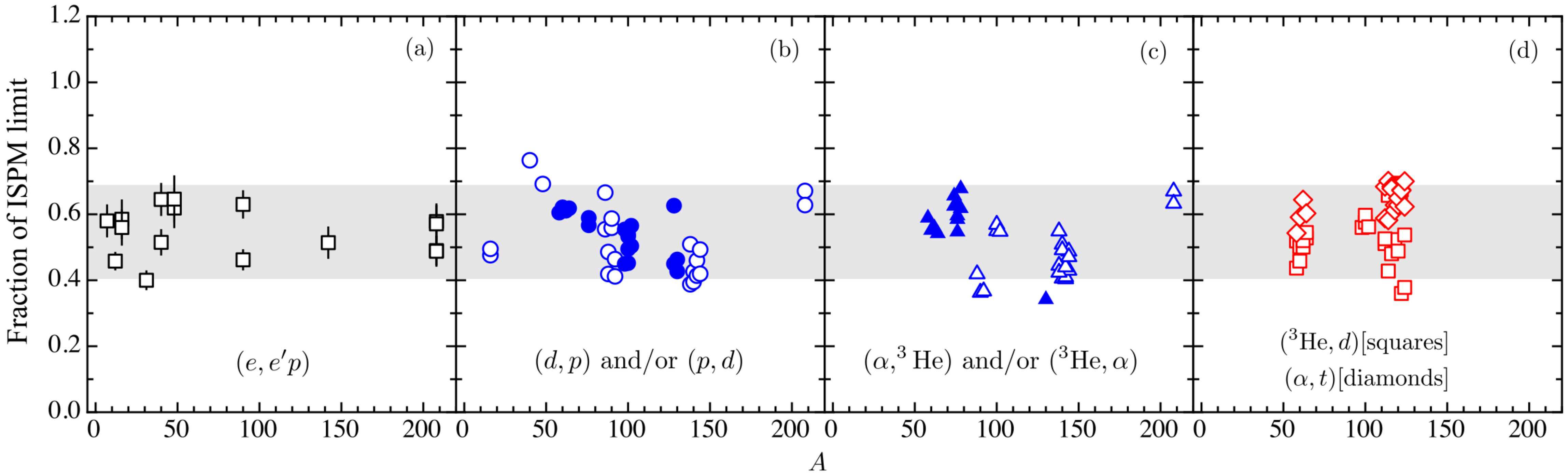


Fig. 29. Observed *s.p.* strength compared to that of the independent-particle shell-model (IPSM) limit as a function of mass A. The $(e, e'p)$ data in Panel (a) are from Refs. [237]. The gray band represents the mean $\pm 2\sigma$ of the $(e, e'p)$ data to guide the eye. The data in Panels (b), (c), and (d), are from the analysis presented in Ref. [238]. Solid symbols are from adding and removing reactions while the empty ones are from just adding or just removing.

compared with independent-particle shell-model

[1] T. Aumann, C. Barbieri, D. Bazin, C. A. Bertulani, A. Bonaccorso, W. H. Dickhoff, A. Gade, M. Gómez-Ramos, B. P. Kay, A. M. Moro et al., Quenching of single-particle strength from direct reactions with stable and rare-isotope beams, Prog. Part. Nucl. Phys. 118, 103847 (2021).

Some results

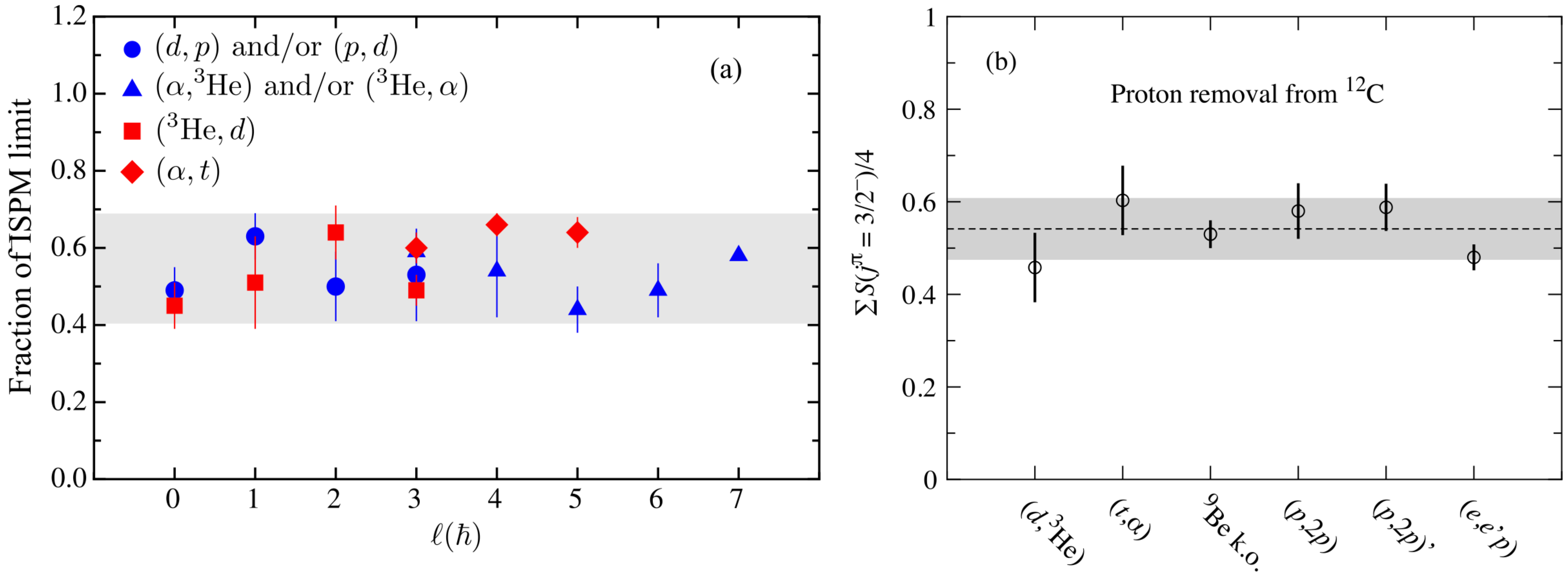
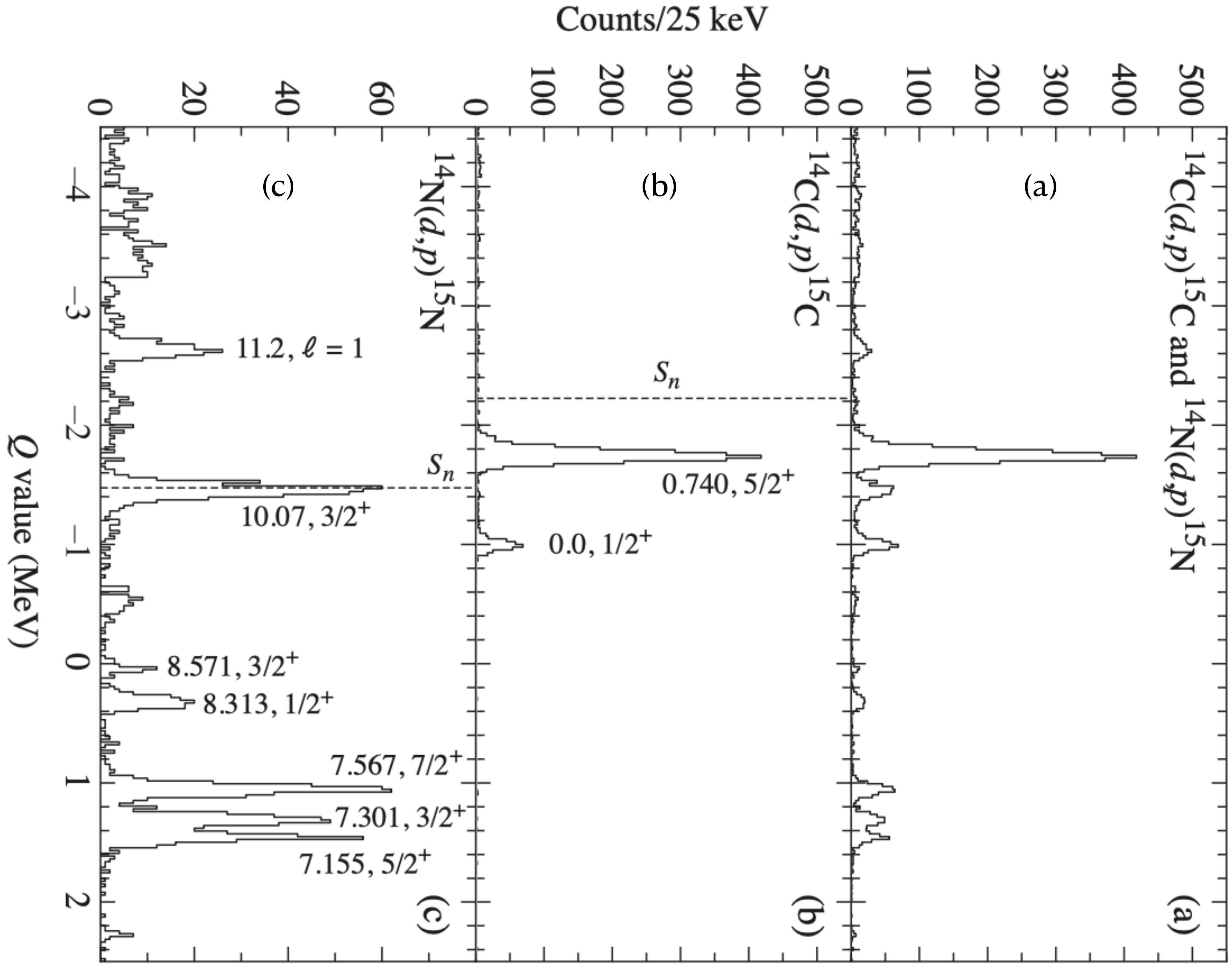


Fig. 30. (a) Average of the quenching factor for different ℓ transfer. The error bars shown represent the rms spread in values. Figure reprinted with permission from Ref. [238]©2013 by the American Physical Society. (b) The sum of the $3/2^-$ strength below ^{12}C as probed via the $(d, {}^3\mathrm{He})$ and (t, α) proton-removal reactions, ^{9}Be-induced knockout, proton-induced $(p, 2p)$ knockout in both 'normal' and inverse kinematics, and lepton-induced $(e, e'p)$ proton knockout, as a fraction of the simple shell-model sum rule limit of 4—that is to say, the quenching factor. The average, 0.53(10) (excluding the ^{9}Be-induced knockout as the excited state is missing), is indicated by the horizontal dashed line.

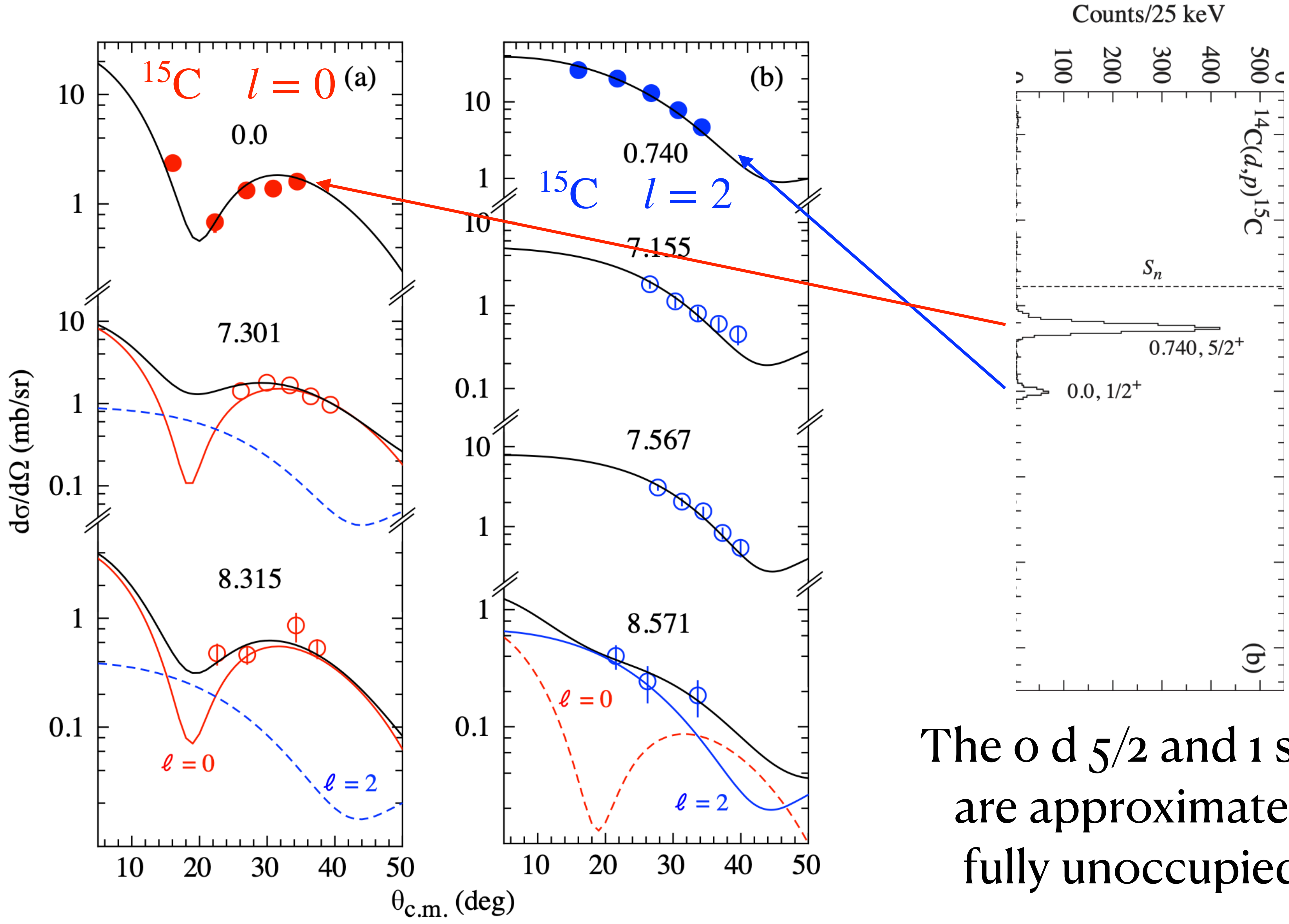
[1] T. Aumann, C. Barbieri, D. Bazin, C. A. Bertulani, A. Bonaccorso, W. H. Dickhoff, A. Gade, M. Gómez-Ramos, B. P. Kay, A. M. Moro et al., Quenching of single-particle strength from direct reactions with stable and rare-isotope beams, Prog. Part. Nucl. Phys. 118, 103847 (2021).

Q-value spectrum



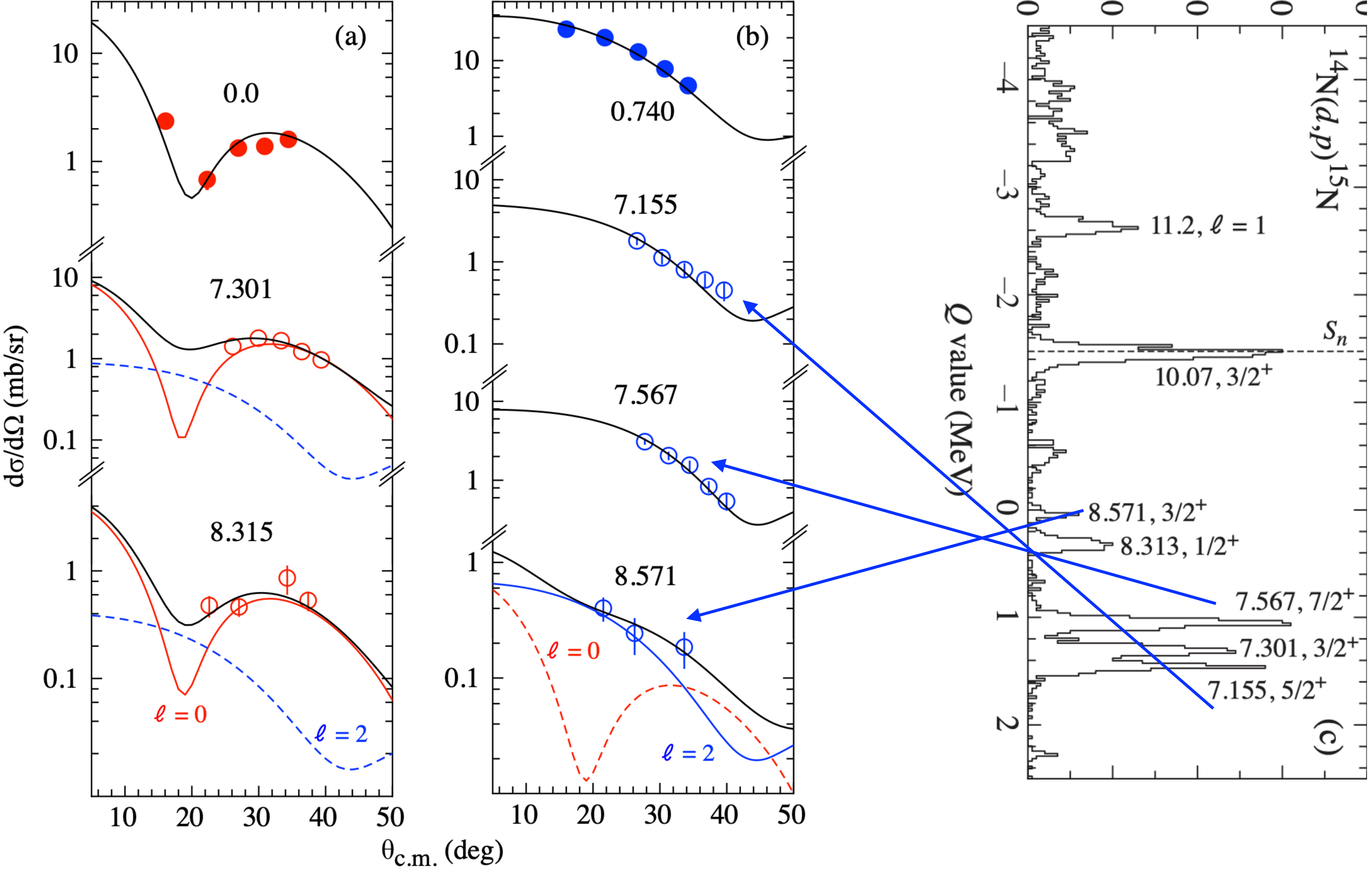
$^{14}N(d,p)^{15}N$ $^{14}C(d,p)^{15}C$ Total

Fitting for different state

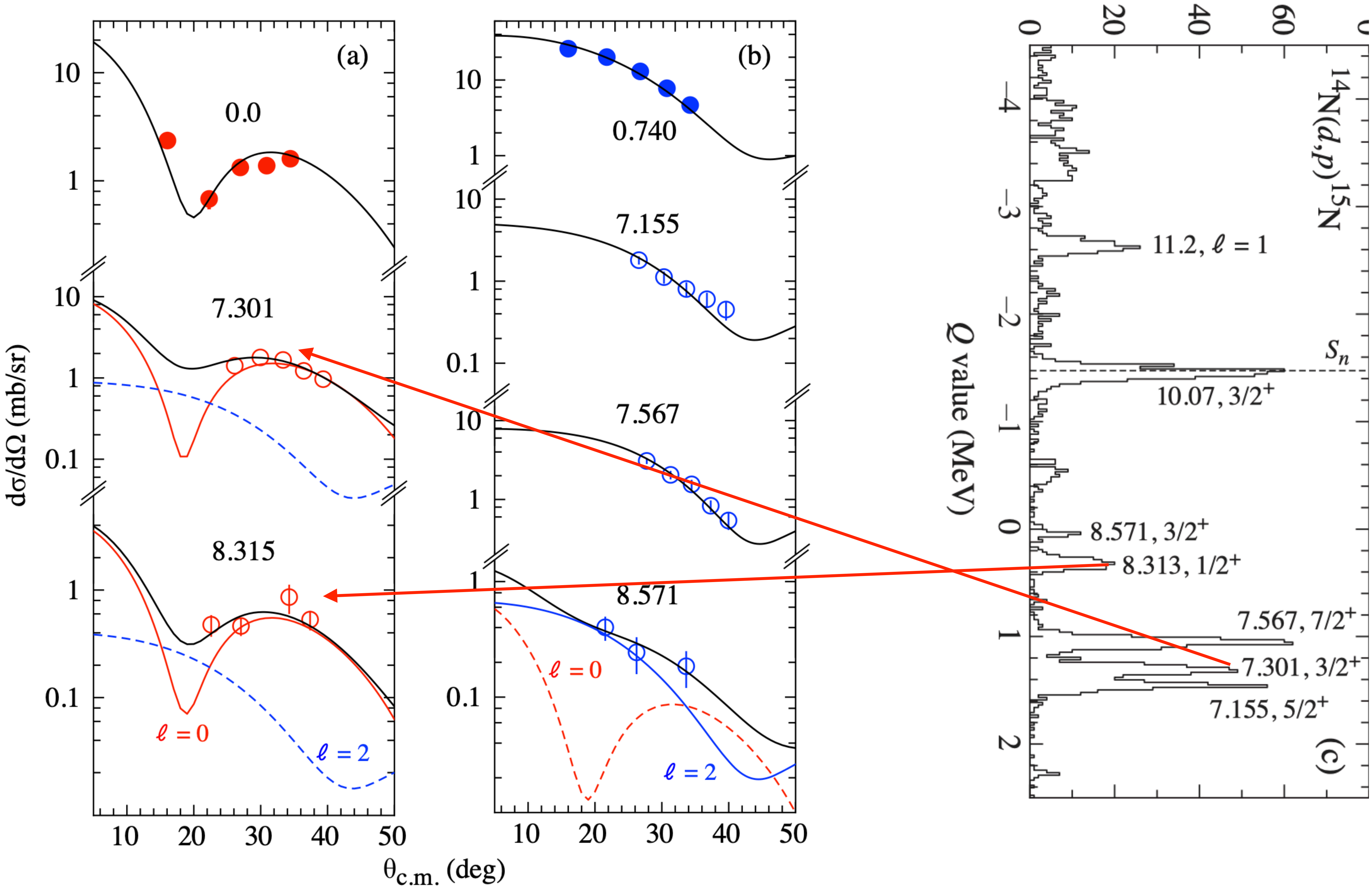


The 0 d 5/2 and 1 s 1/2 are approximately fully unoccupied.

Fitting for different state



Fitting for different state



Questions about the fitting

How to fit?

$$\frac{d\sigma}{d\Omega} = g_0 S_0 \frac{d\sigma}{d\Omega}\bigg|_{l=0} + g_2 S_2 \frac{d\sigma}{d\Omega}\bigg|_{l=2} \quad ?$$

Quenching factor

$$R = \frac{SF_{exp}}{SF_{SM}}$$

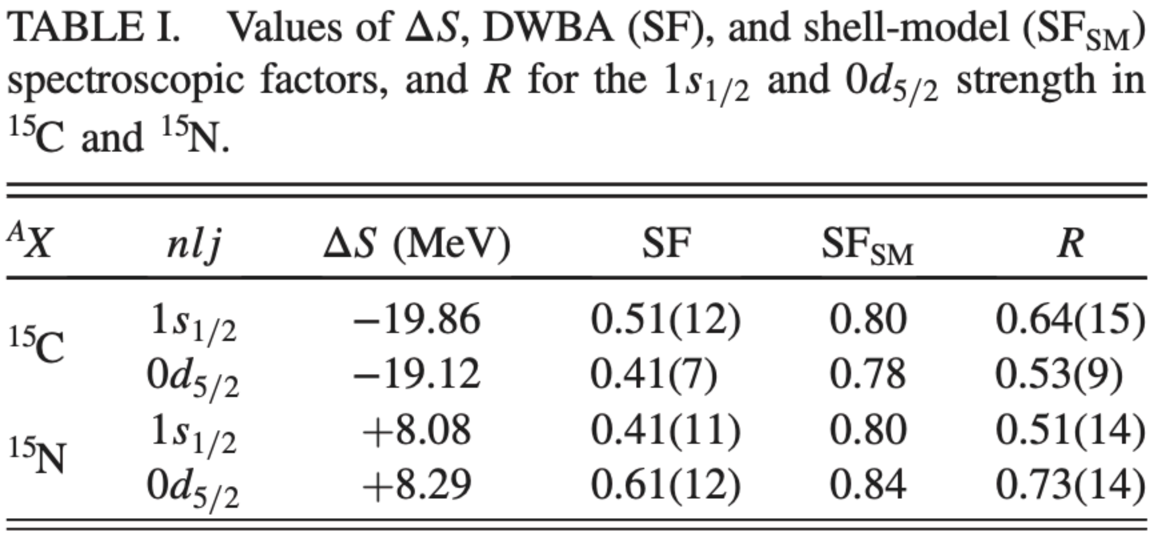


TABLE I. Values of ΔS, DWBA (SF), and shell-model ($\mathrm{SF_{SM}}$) spectroscopic factors, and R for the $1s_{1/2}$ and $0d_{5/2}$ strength in ^{15}C and ^{15}N.

^{A}X	nlj	ΔS (MeV)	SF	$\mathrm{SF_{SM}}$	R
^{15}C	$1s_{1/2}$	−19.86	0.51(12)	0.80	0.64(15)
	$0d_{5/2}$	−19.12	0.41(7)	0.78	0.53(9)
^{15}N	$1s_{1/2}$	+8.08	0.41(11)	0.80	0.51(14)
	$0d_{5/2}$	+8.29	0.61(12)	0.84	0.73(14)

Another way? couple $\sqrt{S_0}\psi_{sp}^{l=0}(r)$ and $\sqrt{S_2}\psi_{sp}^{l=2}(r)$ with CG

Are there any overlap between these two states when doing numerical calculation?

Consider coupled channel (CC) calculation?