An analysis of the ^{18g,m}F (d,p)^{19}F reactions in the rotational model

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Collaborators

An analysis of the $^{18}\mathbf{F}^{g,m}(d,p)^{19}\mathbf{F}$ reactions in the rotational model

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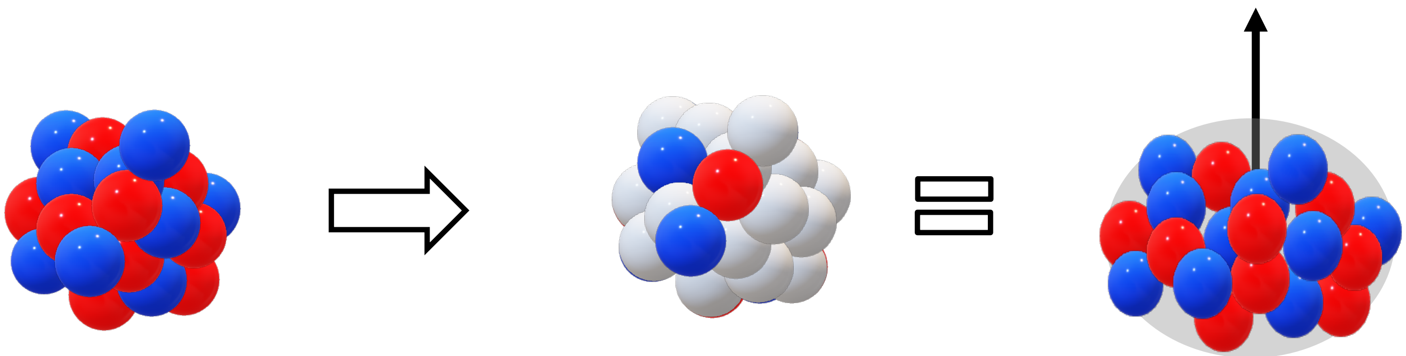
Single Particle Structure and Collectivity in Light Nuclei

"It was quite a dramatic moment when it was realized that some of the spectra in the light nuclei could be given a very simple interpretation in terms of the rotational coupling scheme." – A. Bohr, 1975 Nobel Lecture



- Duality of single-particle and collective model descriptions for atomic nuclei has been recognized for decades
- ^{19}F was an early example, where shell-model calculations in the *sd* model space with only 3 valence nucleons outside ^{16}O *and* a rotational model description both reproduced experimental energy levels

J. P. Elliot and B.H. Flowers, Proc. R. Soc. A **229**, 536 (1955).
M. Redlich, Phys. Rev. **99**, 1427 (1955).
E. B. Paul, Philosophical Magazine, **311**, 2:15 (1957).

Coriolis effects and rotation alignment in nuclei*†

F. S. Stephens

Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

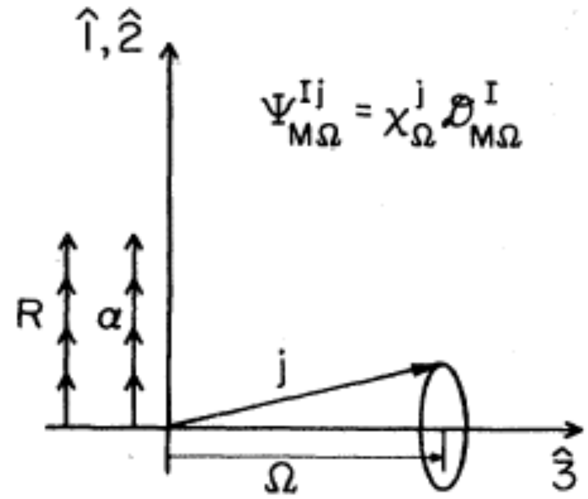
$$H = H_p + H_{\rm rot} = H_p + (\hbar^2/2\mathfrak{J})\mathbf{R}^2$$
$$= H_p + (\hbar^2/2\mathfrak{J})(R_x^2 + R_y^2),$$

$$H = H_p + (\hbar^2/2\mathfrak{J})[I(I+1) - K^2] + H_c$$
$$+ (\hbar^2/2\mathfrak{J})[\langle \mathbf{j}^2 \rangle - \Omega^2],$$

$$E_{\rm Cor}(\max) \approx 2(\hbar^2/2\mathfrak{J})Ij.$$

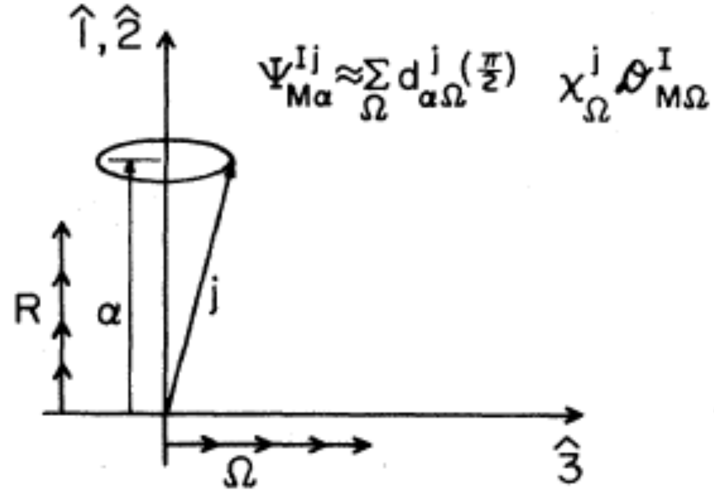
Coupling Limits

Deformation aligned
Strongly coupled



$H_c/\Delta E << 1$

Rotation aligned
Decoupled



$H_c/\Delta E >> 1$

$^{18}F(d,p)^{19}F$

PHYSICAL REVIEW LETTERS **120,** 122503 (2018)

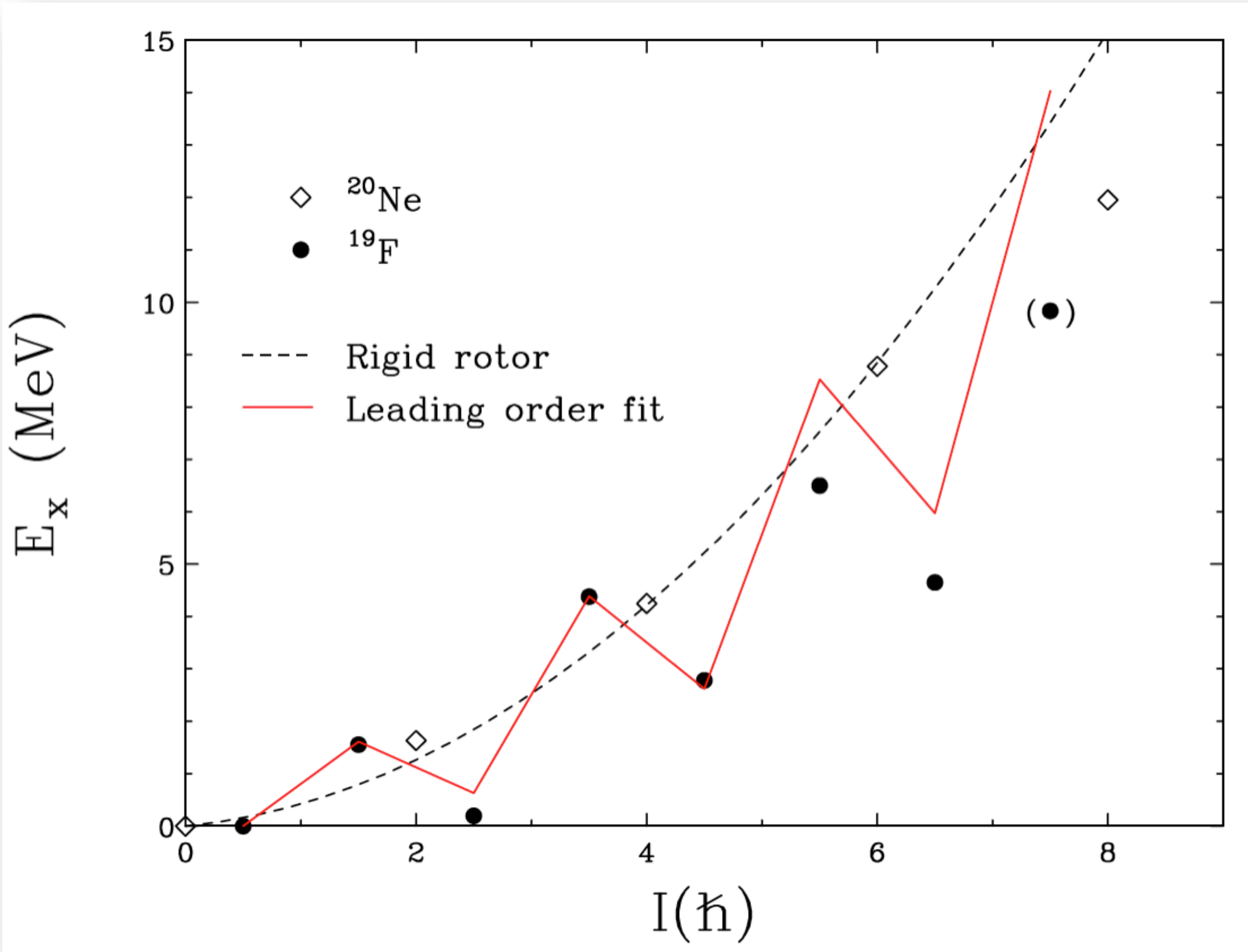
Probing the Single-Particle Character of Rotational States in ^{19}F Using a Short-Lived Isomeric Beam

D. Santiago-Gonzalez,[1,2] K. Auranen,[2] M. L. Avila,[2] A. D. Ayangeakaa,[2,*] B. B. Back,[2] S. Bottoni,[2,†] M. P. Carpenter,[2] J. Chen,[2] C. M. Deibel,[1] A. A. Hood,[1] C. R. Hoffman,[2] R. V. F. Janssens,[2,‡] C. L. Jiang,[2] B. P. Kay,[2] S. A. Kuvin,[3] A. Lauer,[1] J. P. Schiffer,[2] J. Sethi,[4,2] R. Talwar,[2] I. Wiedenhöver,[5] J. Winkelbauer,[6] and S. Zhu[2]

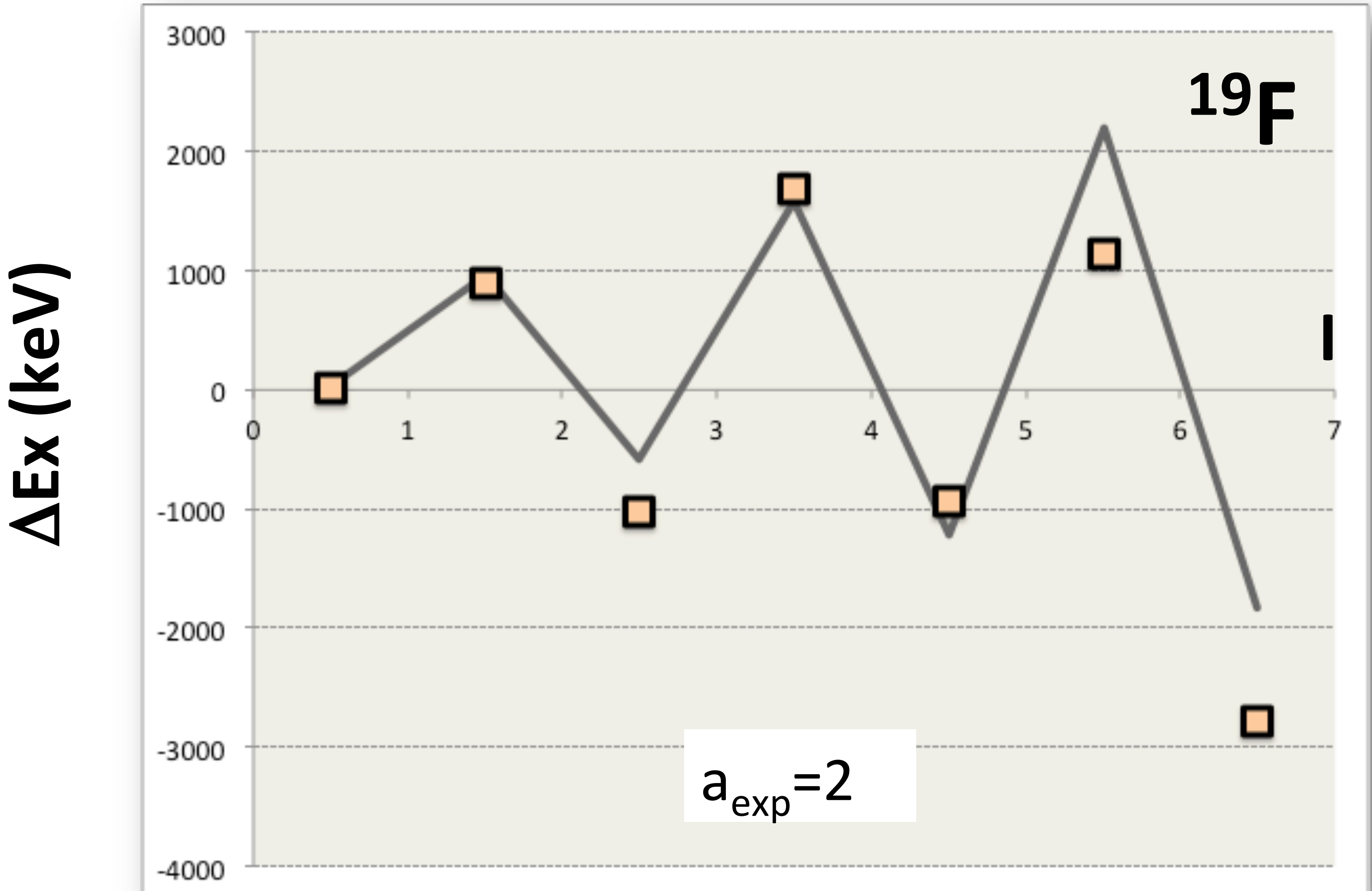
A beam containing a substantial component of both the $J^{\pi} = 5^{+}$, $T_{1/2} = 162$ ns isomeric state of ^{18}F and its 1^{+}, 109.77-min ground state has been utilized to study members of the ground-state rotational band in ^{19}F through the neutron transfer reaction (d,p) in inverse kinematics. The resulting spectroscopic strengths confirm the single-particle nature of the $13/2^{+}$ band-terminating state. The agreement between shell-model calculations, using an interaction constructed within the *sd* shell, and our experimental results reinforces the idea of a single-particle/collective duality in the descriptions of the structure of atomic nuclei.

HELIOS Experiment at ATLAS/ANL

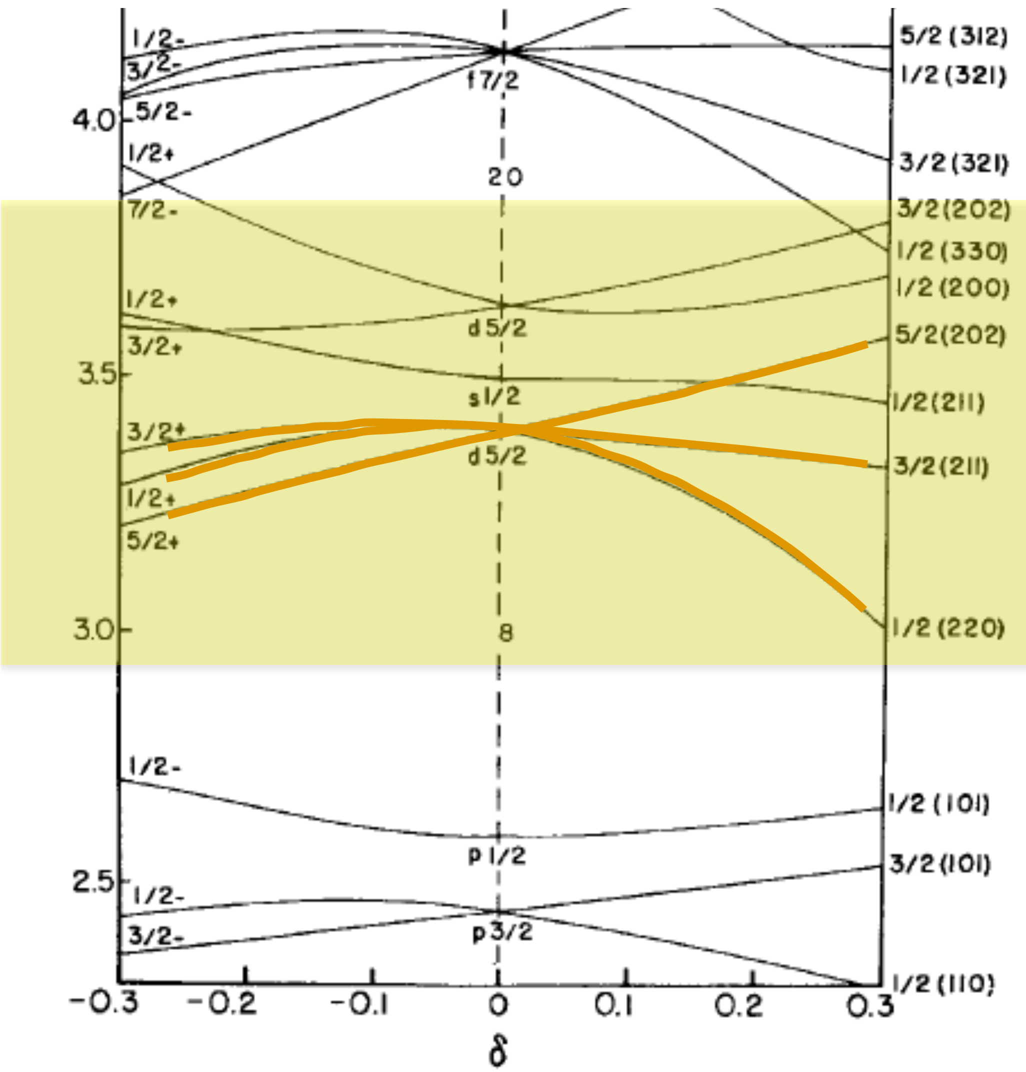
^{19}F in the Rotational Model



^{19}F in the Rotational Model



^{19}F in the Rotational Model



$\frac{1}{2}[220]$, $\frac{3}{2}[211]$, and $\frac{5}{2}[202]$

^{19}F in the Rotational Model

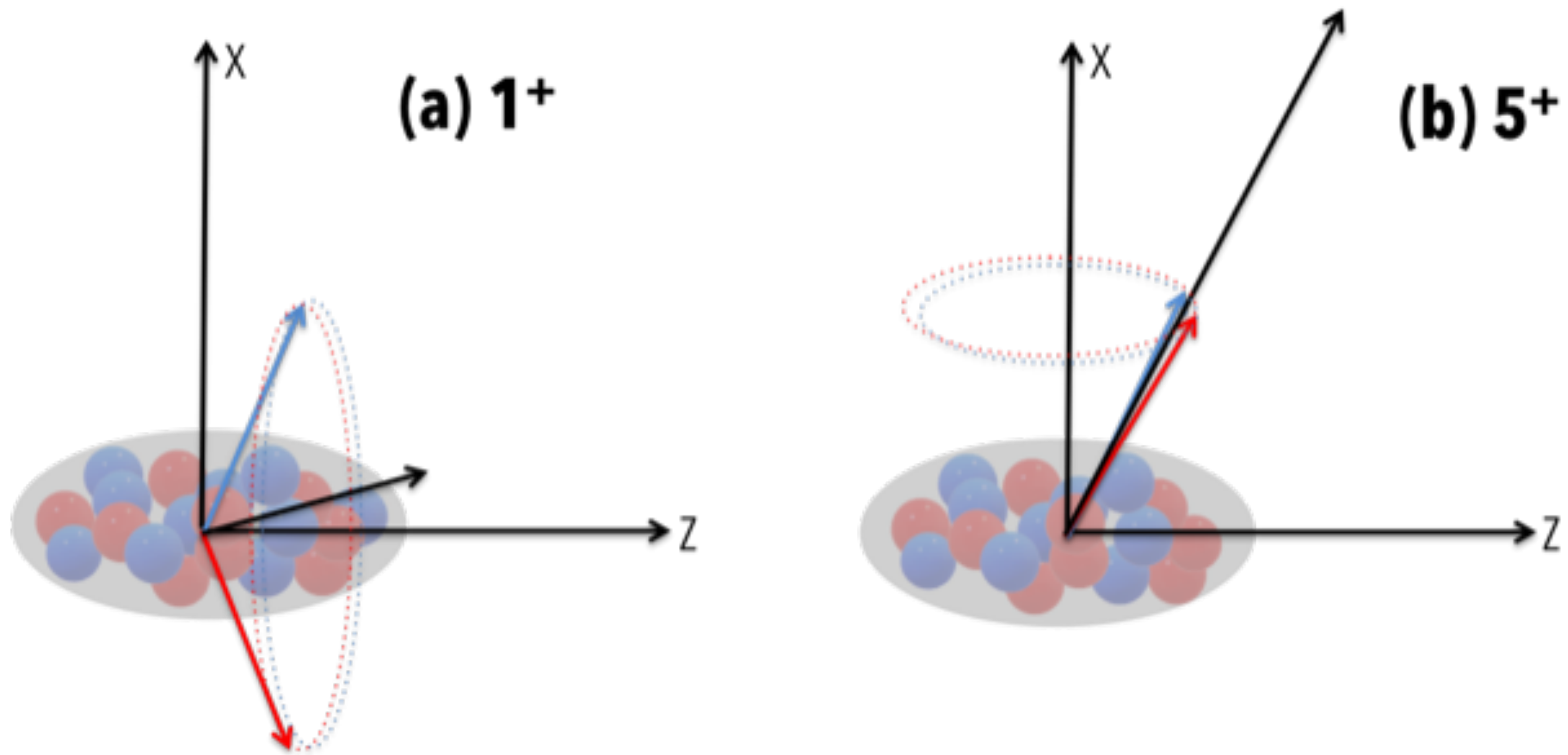
$\frac{1}{2}[220],\ \frac{3}{2}[211],\ \text{and}\ \frac{5}{2}[202]$

$$|\tfrac{1}{2}[220]\rangle = C_{1/2,0,1/2}|s_{1/2}\rangle + C_{3/2,2,1/2}|d_{3/2}\rangle + C_{5/2,2,1/2}|d_{5/2}\rangle$$

$$|\tfrac{3}{2}[211]\rangle = C_{3/2,2,3/2}|d_{3/2}\rangle + C_{5/2,2,3/2}|d_{5/2}\rangle$$

$$|\tfrac{5}{2}[202]\rangle = |d_{5/2}\rangle$$

^{18}F in the Rotational Model

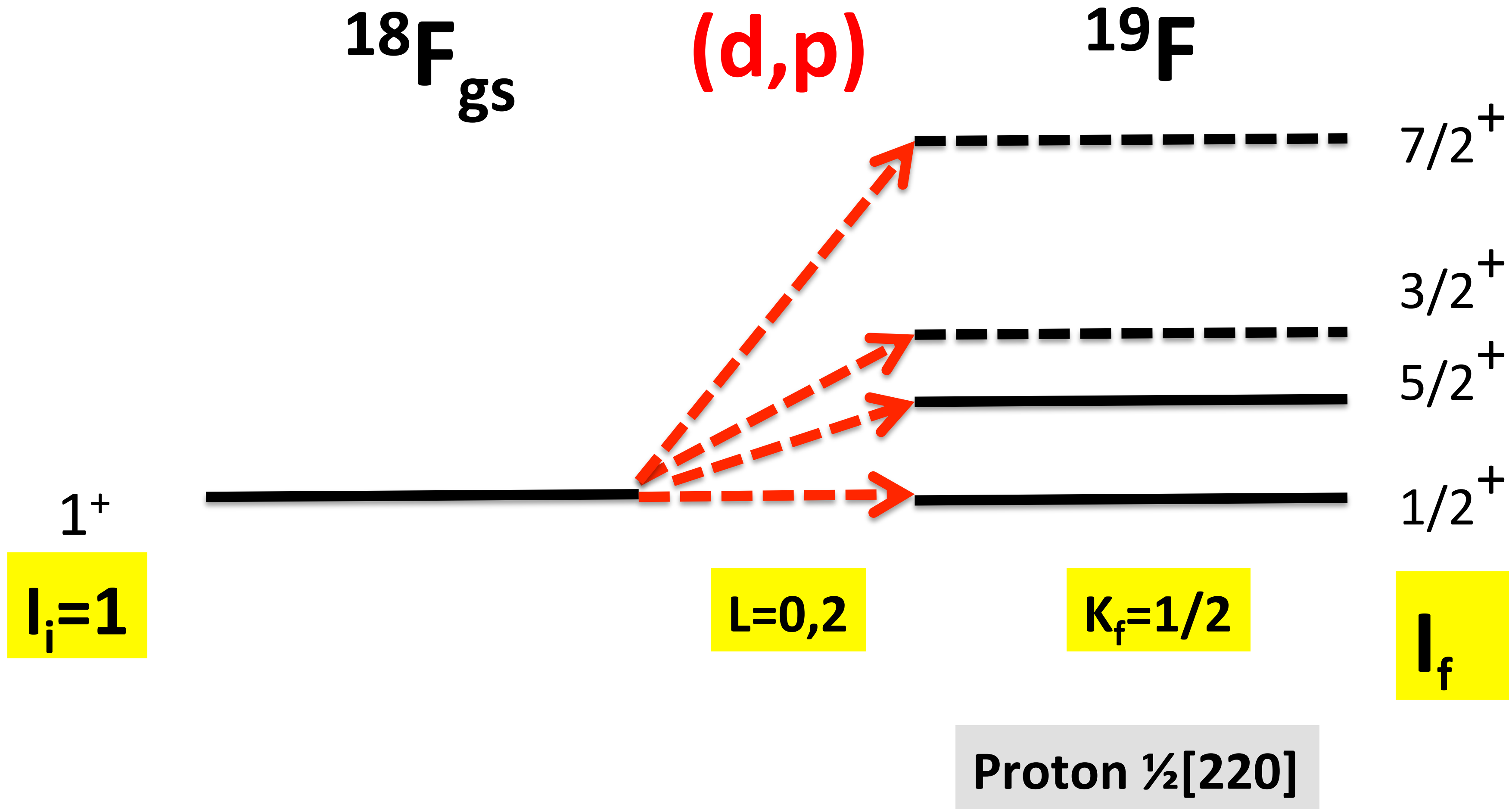


Strongly Coupled band

Doubly-decoupled band

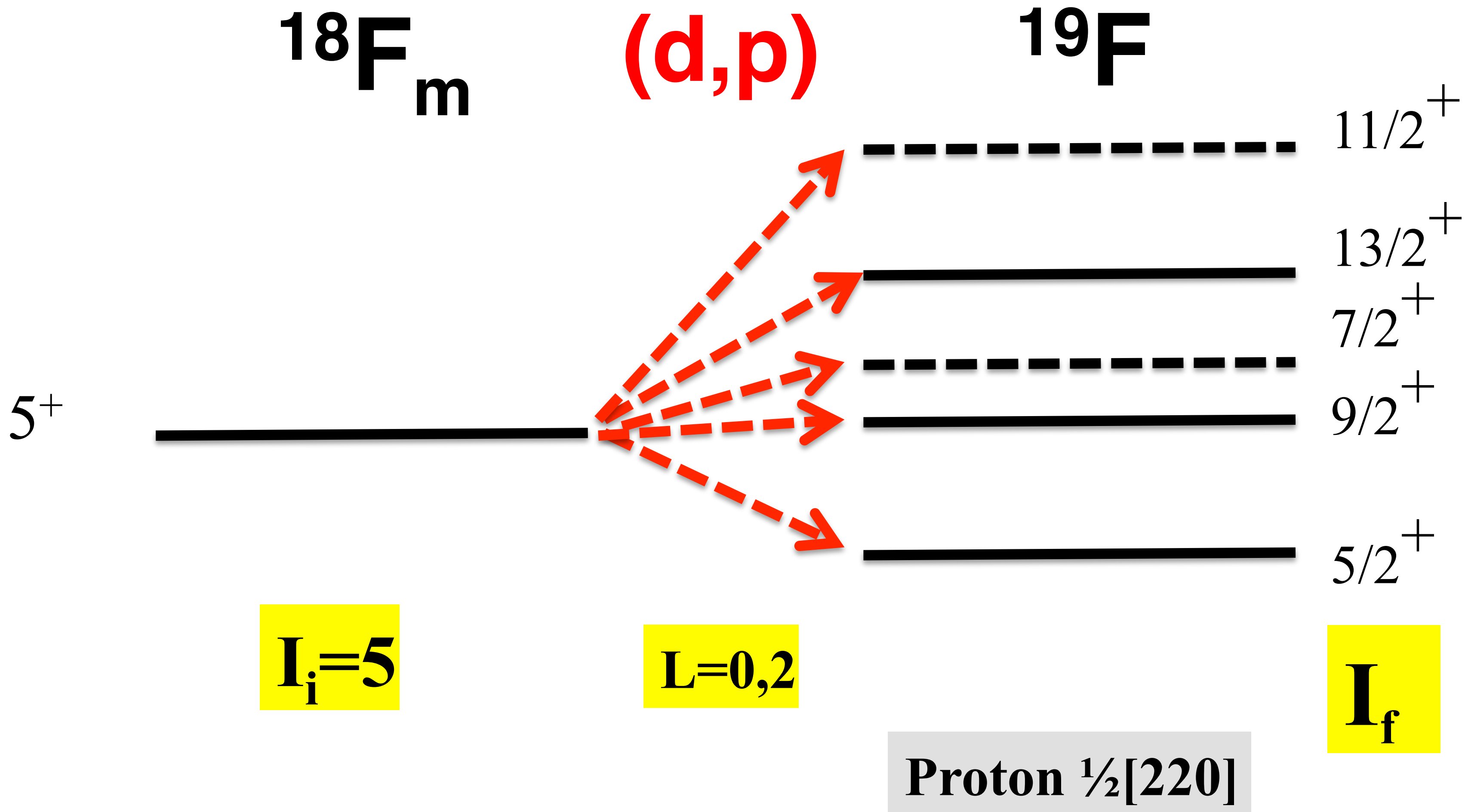
A. J. Kreiner, Z. Physik A 288 373, (1978)

$^{18}F_{gs}(d,p)^{19}F$ in the Nilsson formalism



Strong Coupling

$^{18}F_m(d,p)^{19}F$ in the Nilsson formalism



Decoupling

$^{18}F(d,p)^{19}F$ in the Nilsson formalism

Deformation aligned coupling – strongly coupled band

$$S_{i,f}(j\ell,K) = \frac{(2I_i+1)}{(2I_f+1)}\left(\langle I_i j \Omega_\nu K_i | I_f K_f\rangle C_{j,\ell} U_\nu \langle \phi_f | \phi_i \rangle\right)^2$$
$$= \frac{(2I_i+1)}{(2I_f+1)}\theta_{i,f}(j\ell,K)^2$$

Rotation aligned coupling – decoupled band

$$S_{i,f}(j\ell) = \frac{(2I_i+1)}{(2I_f+1)}\left(\sum_K \mathcal{A}_K \theta_{i,f}(j\ell,K)\right)^2$$

$$\psi_I = \sum_K \mathcal{A}_K |IK\rangle.$$

B. Elbek and P. Tjom, Advances in Nucl. Phys. Vol 3, 259 (1969).
R. G. Lanier, et al., Phys. Rev. 178, 1919 (1969).

G. Th. KASCHL, et al. Nucl. Phys. A155 (1970) 417-444

Ingredients

Ground-state

$$S_{i,f}(j\ell, K) = \frac{(2I_i+1)}{(2I_f+1)} \langle I_i j \Omega_\nu K_i | I_f K_f \rangle^2 C^2_{j,\ell,\nu} U^2_\nu \langle \phi_f | \phi_i \rangle^2$$

Isomer

$$\psi_I = \sum_K \mathcal{A}_K |IK\rangle$$

Nilsson amplitudes

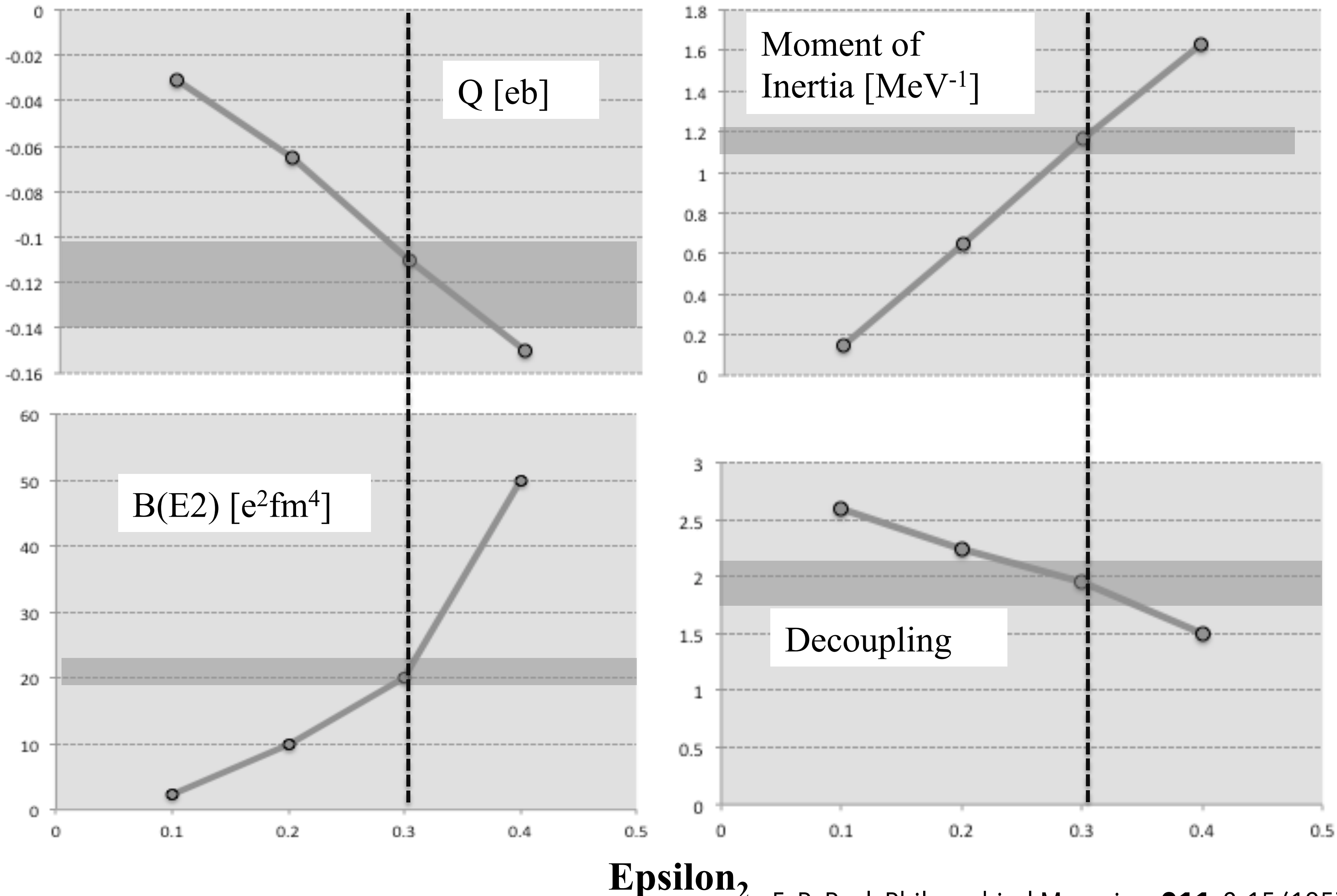
BCS

Spectator proton wf

$$\mathcal{A}_K \approx d^{5/2}_{5/2,K}(\pi/2)$$

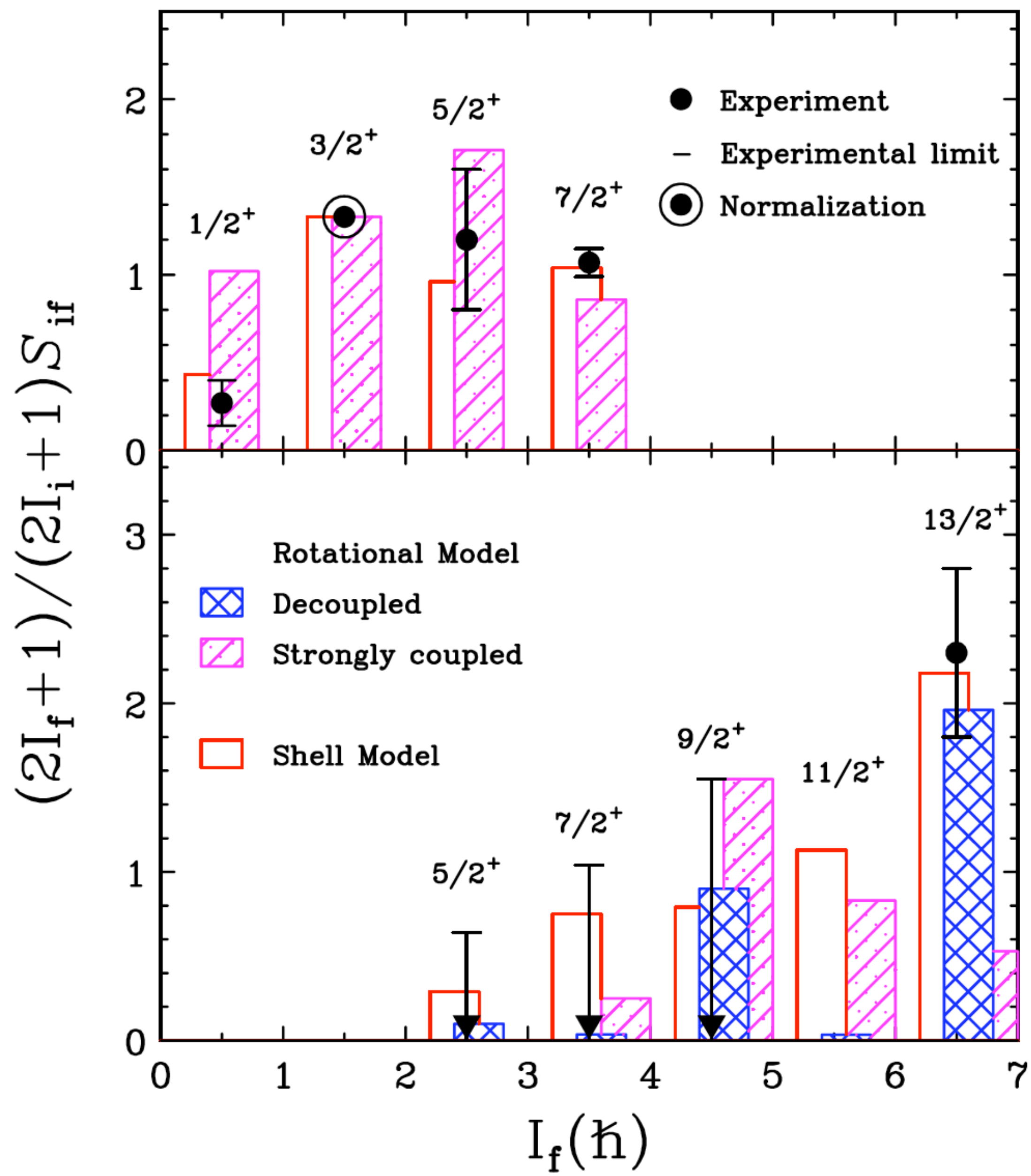
F. S. Stephens, R. M. Diamond, and S. G. Nilsson, Phys. Lett. B 44, 429 (1973)

Choice of deformation



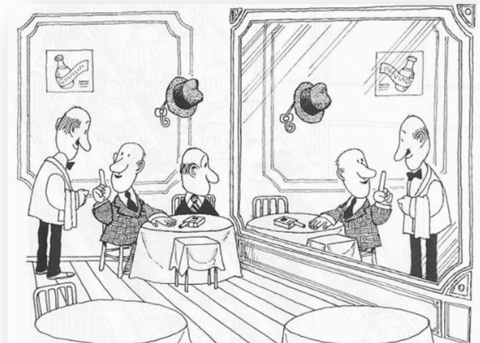
E. B. Paul, Philosophical Magazine, **311**, 2:15 (1957)

Results



$(2I_f+1)/(2I_i+1)S_{if}$
$I_f(\hbar)$
Experiment
Experimental limit
Normalization
1/2+
3/2+
5/2+
7/2+
Rotational Model
Decoupled
Strongly coupled
Shell Model
5/2+
7/2+
9/2+
11/2+
13/2+

… and isospin?



^{19}Ne

$11/2^+$ - - - - - -

$13/2^+$ ———

$7/2^+$ - - - - - -

$9/2^+$ ———

$3/2^+$ - - - - - -

$5/2^+$ ———

$1/2^+$ ———

Neutron ½[220]

^{19}F

- - - - - - $11/2^+$

——— $13/2^+$

- - - - - - $7/2^+$

——— $9/2^+$

- - - - - - $3/2^+$

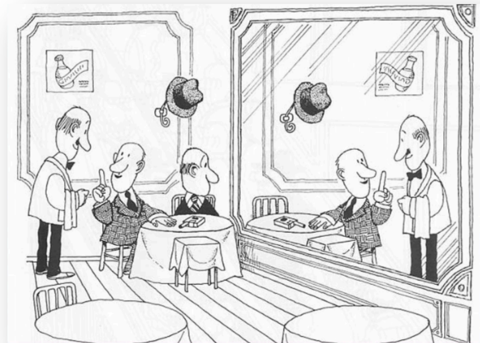
——— $5/2^+$

——— $1/2^+$

Proton ½[220]

M. A. Bentley and S. M. Lenzi, Progress in Particle and Nuclear Physics, 59, 2, 497 (2007).

… and isospin?



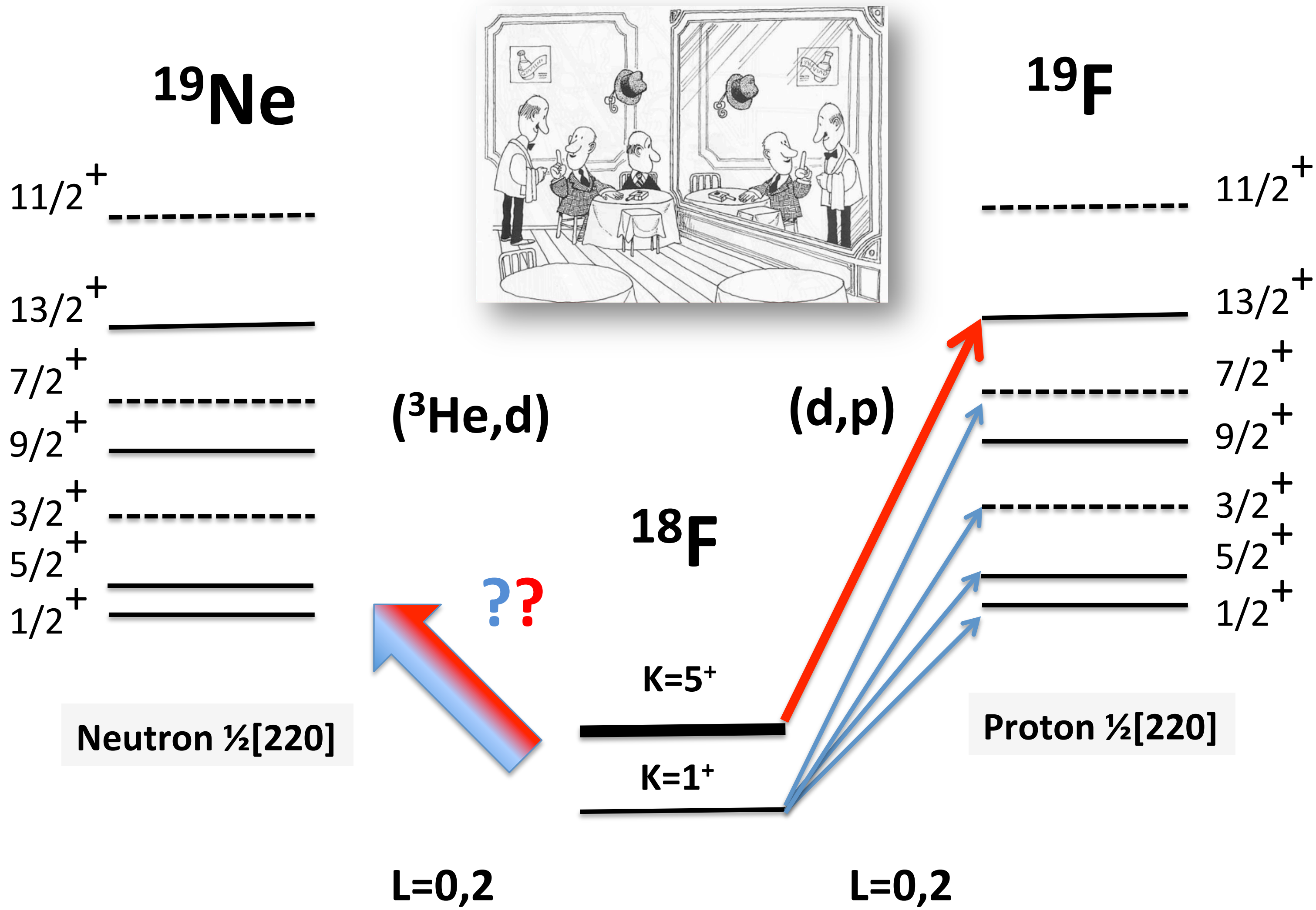
^{19}Ne		^{19}F
$11/2^+$	- - - - - -	$11/2^+$
$13/2^+$	———	$13/2^+$
$7/2^+$		$7/2^+$
$9/2^+$		$9/2^+$
$3/2^+$		$3/2^+$
$5/2^+$		$5/2^+$
$1/2^+$		$1/2^+$

TABLE I: Comparison of experimental magnetic moments in ^{19}F and ^{19}Ne [23] with the Nilsson calculations, using $g_R = Z/A$ and $g_s = 0.95(g_s)_{free}$.

Nucleus	State	μ Experiment (μ_N)	μ Nilsson (μ_N)
^{19}F	$1/2^+$	2.63	2.56
	$5/2^+$	3.60	3.59
^{19}Ne	$1/2^+$	-1.89	-1.74
	$5/2^+$	-0.74	-0.87

M. A. Bentley and S. M. Lenzi, Progress in Particle and Nuclear Physics, 59, 2, 497 (2007).

… and isospin? An interesting experiment:



M. A. Bentley and S. M. Lenzi, Progress in Particle and Nuclear Physics, 59, 2, 497 (2007).

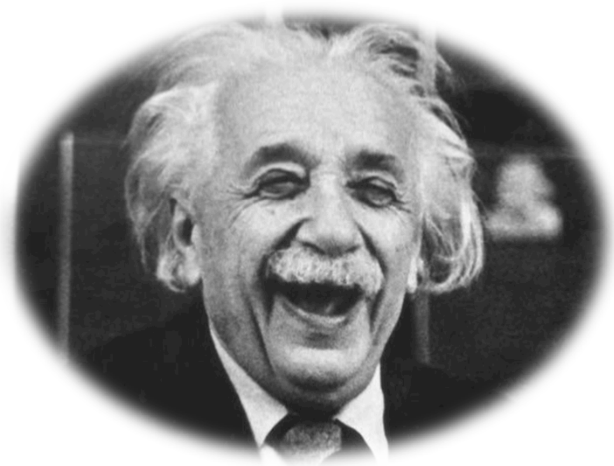
Conclusions

I think it looks good,   however   ……

Conclusions

I think it looks good,   however   ……

I wonder if it passes the audience



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Tante Grazie !