

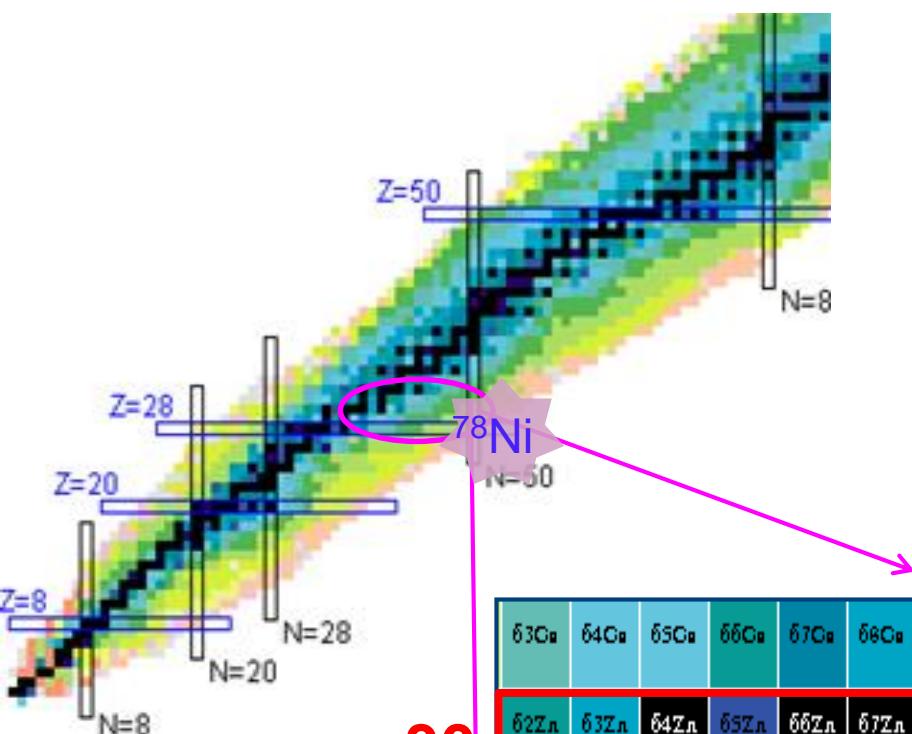
Laser spectroscopy on Zn isotopes and isomers

Spin, moments, charge radii

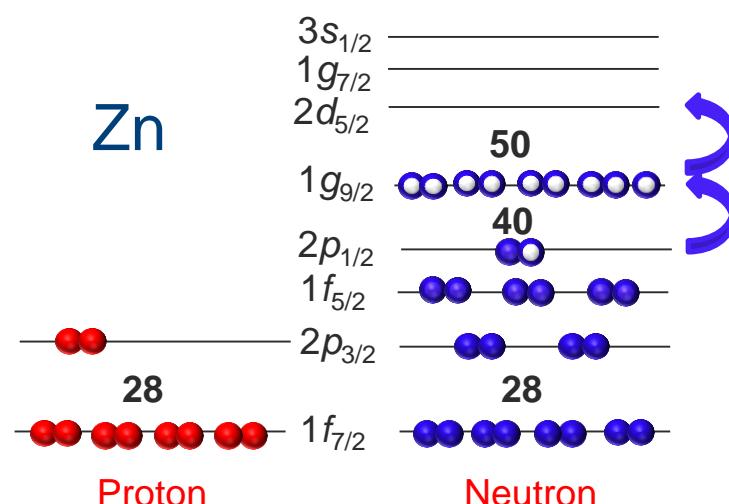
Xiaofei Yang @ IKS KU LEUVEN

Dec 2-4 ISOLDE workshop @CERN

- Motivation
- Collinear laser spectroscopy
- Spins, moments and charge radii
- Summary



Zn



Proton

Neutron

63Co	64Co	65Co	66Co	67Co	68Co	69Co	70Co	71Co	72Co	73Co	74Co	75Co	76Co	77Co	78Co	79Co	80Co	81Co	82Co
62Zn	63Zn	64Zn	65Zn	66Zn	67Zn	68Zn	69Zn	70Zn	71Zn	72Zn	73Zn	74Zn	75Zn	76Zn	77Zn	78Zn	79Zn	80Zn	81Zn
61Cu	62Cu	63Cu	64Cu	65Cu	66Cu	67Cu	68Cu	69Cu	70Cu	71Cu	72Cu	73Cu	74Cu	75Cu	76Cu	77Cu	78Cu	79Cu	80Cu
60Ni	61Ni	62Ni	63Ni	64Ni	65Ni	66Ni	67Ni	68Ni	69Ni	70Ni	71Ni	72Ni	73Ni	74Ni	75Ni	76Ni	77Ni	78Ni	79Ni
59Co	60Co	61Co	62Co	63Co	64Co	65Co	66Co	67Co	68Co	69Co	70Co	71Co	72Co	73Co	74Co	75Co	76Co		

40

50

Investigate the nuclear structure in Zn_{30} isotopic chain (near closed shell $Z=28, N=40, 50$) by measurement of spins, moments and charge radii

Laser Spectroscopy Method

$$\Delta E = \textcolor{red}{A} \cdot K/2 + \textcolor{green}{B} \cdot \{3K(K+1)/4 - I(I+1)J(J+1)\}/\{2(2I-1)(2J-1)IJ\}$$

Hyperfine structure (HFS)-> link between atomic parameters and nucleus parameters

Atomic parameters

- Magnetic dipole HF parameter

$$A = \frac{\mu_I B_J}{IJ}$$

- Electric quadrupole HF parameter

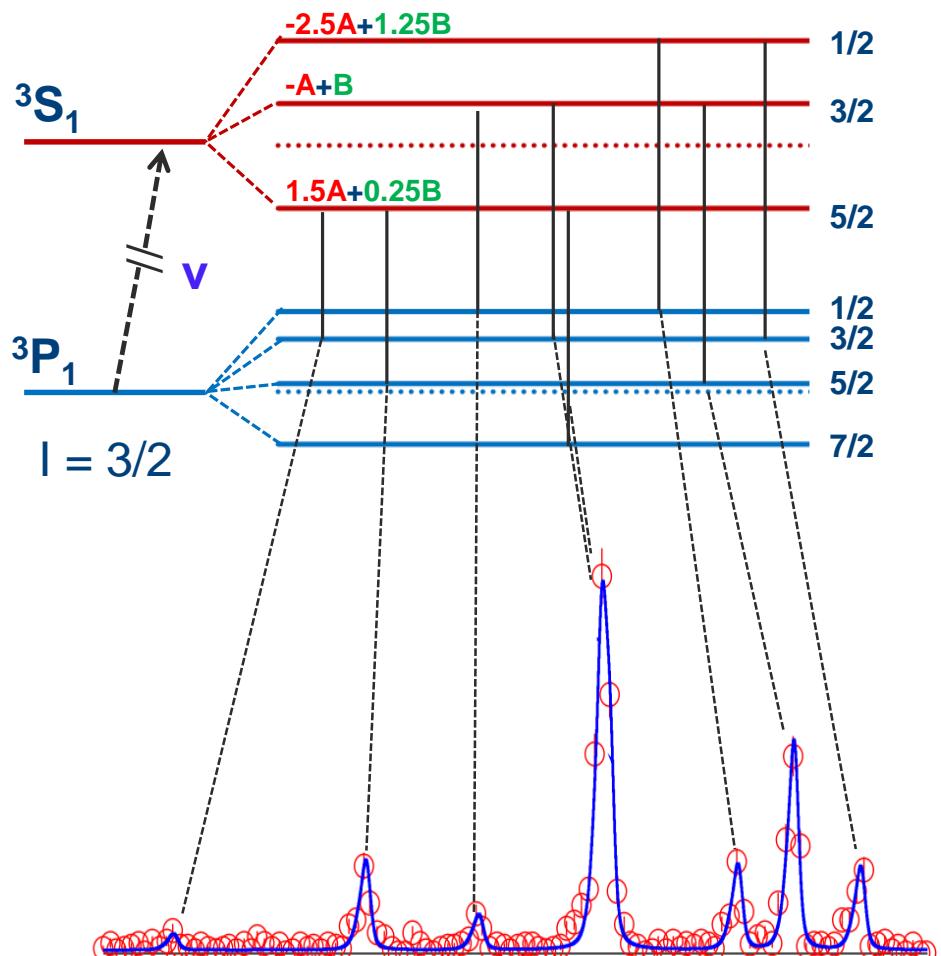
$$B = eQV_{zz}$$

- Centroid v_0
Isotopes shift

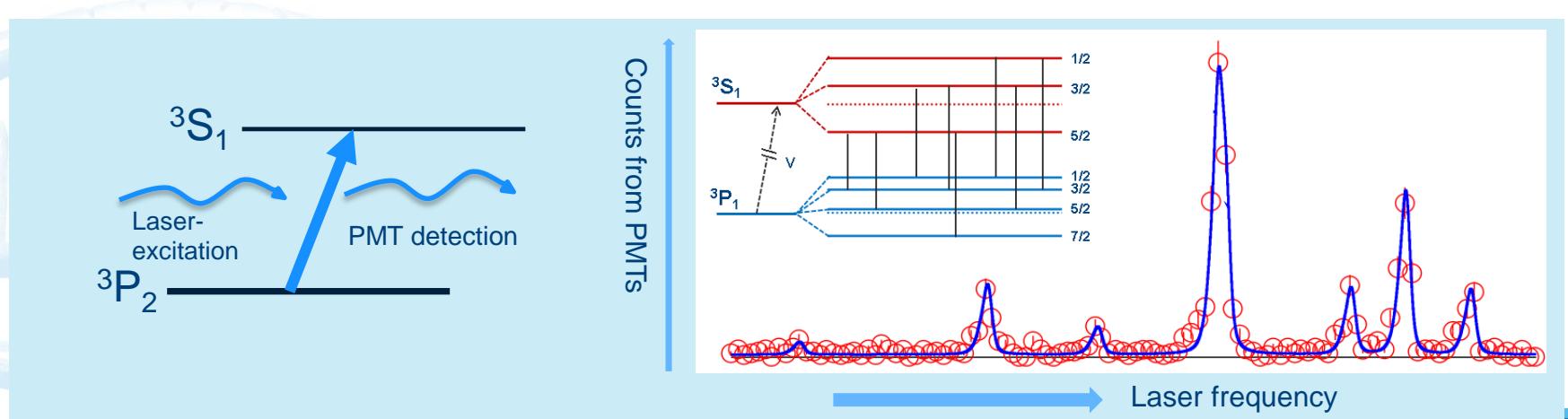
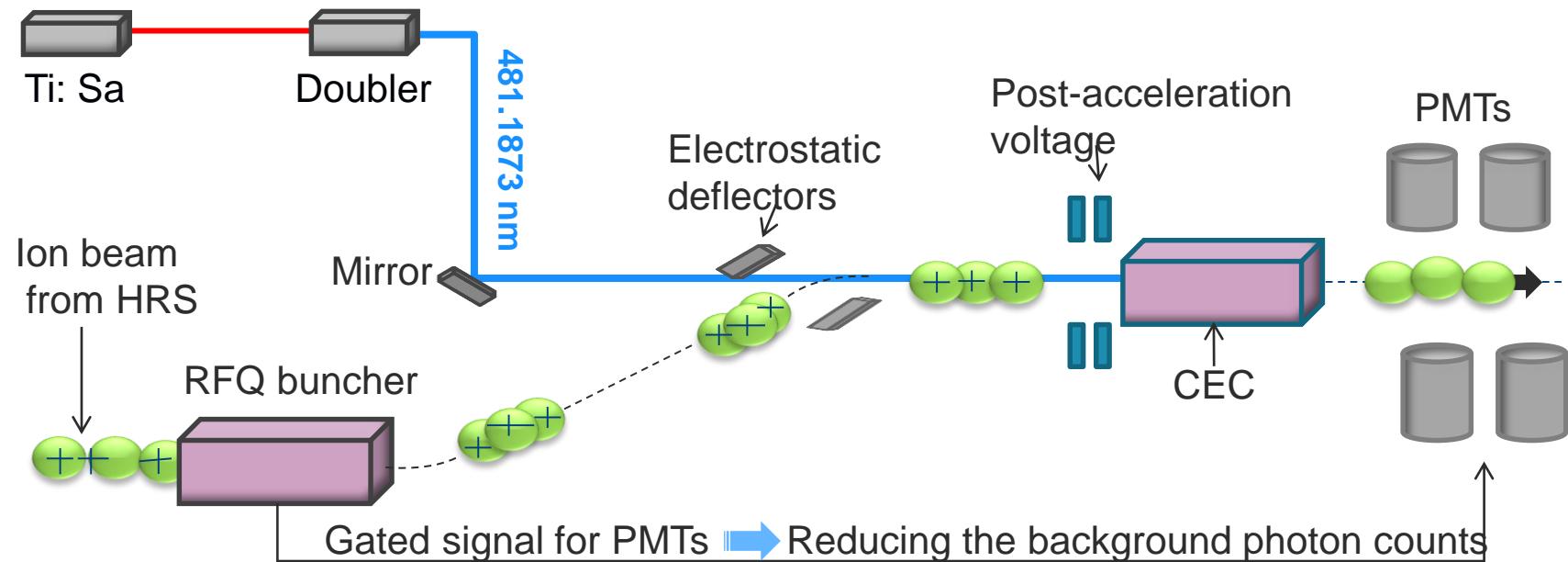
Nucleus parameters

- the nuclear spin I
- the magnetic dipole moment μ
- the electric quadrupole moment Q
- nuclear charge radius $\langle r^2 \rangle$

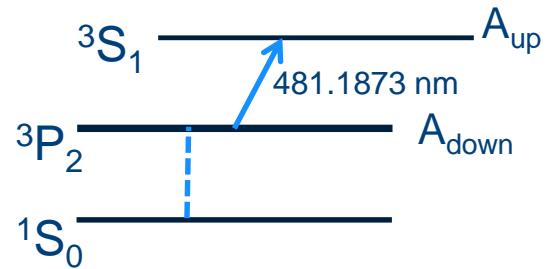
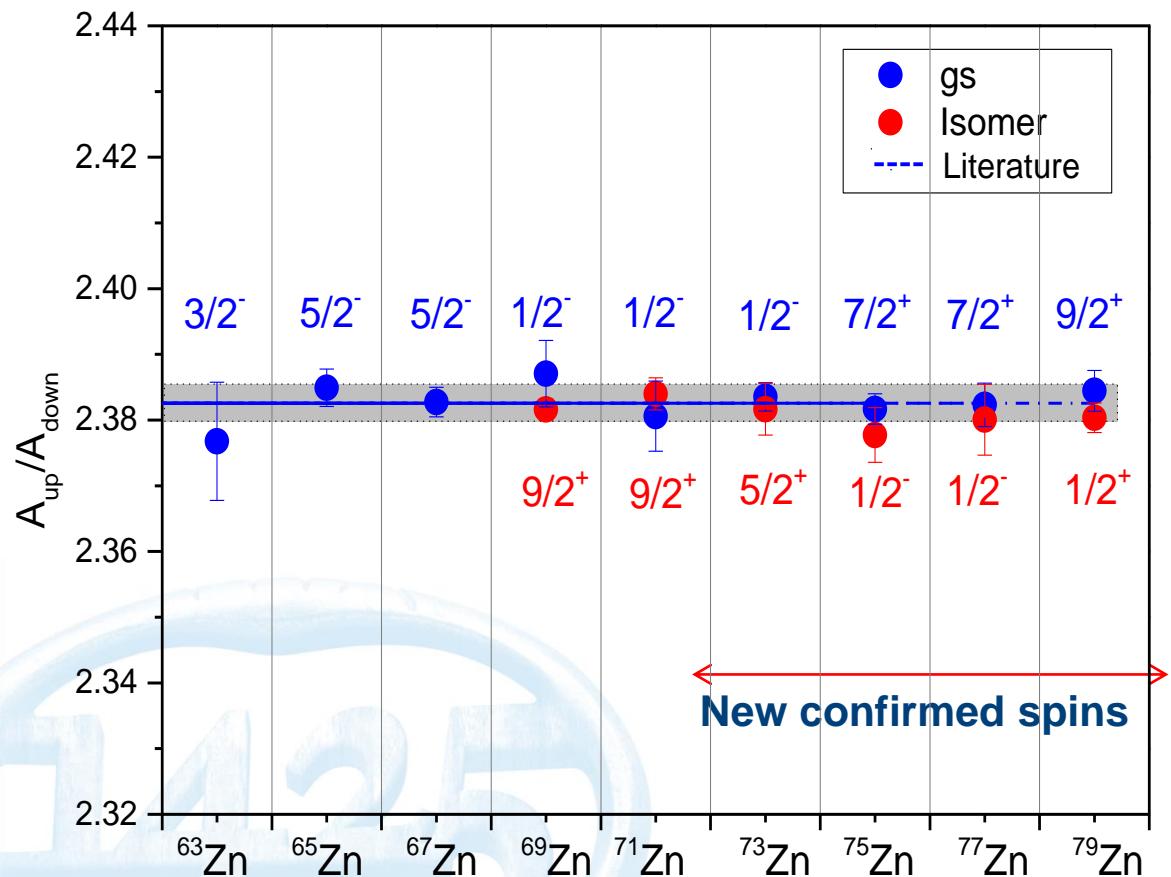
HFS



Collinear Laser Spectroscopy@ ISOLDE - CERN



Assignment of the nuclear spins for isomers and ground states



Ratio $A_{\text{up}}/A_{\text{down}}$:constant
(hyperfine anomaly is negligible)

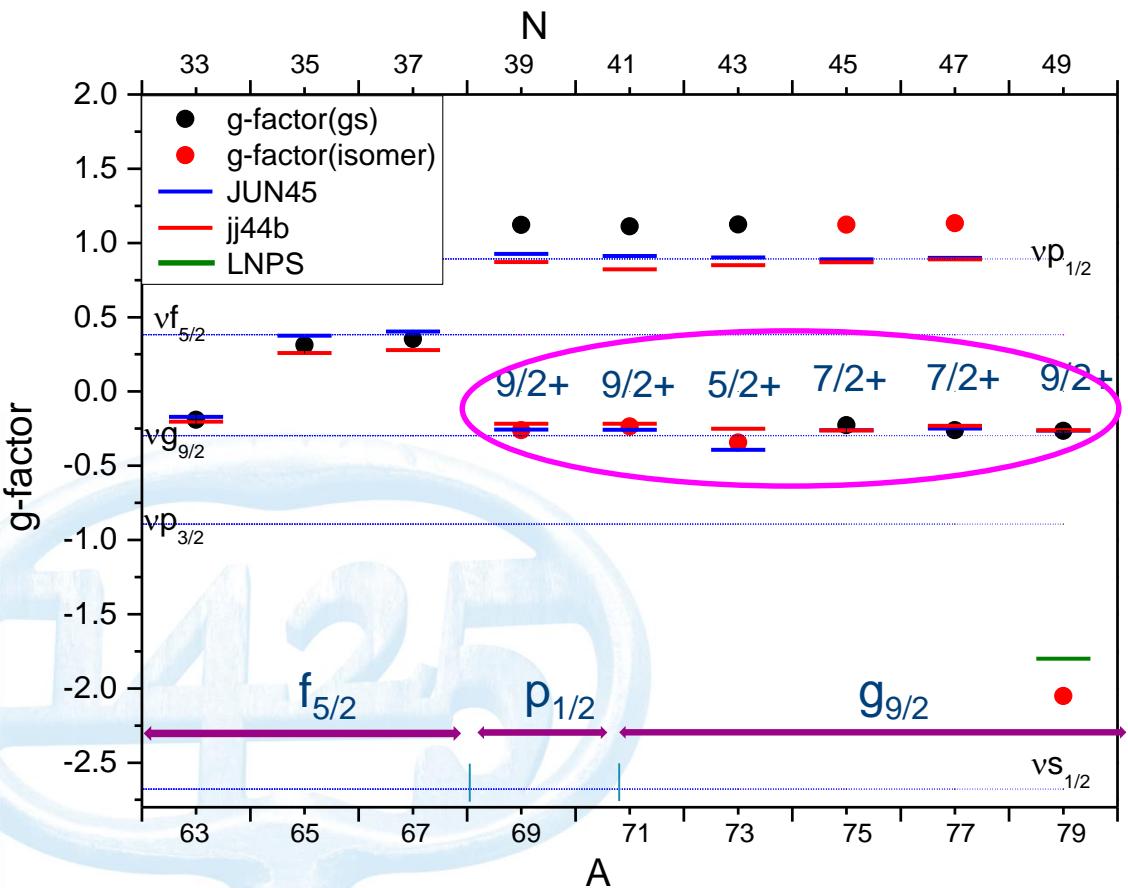
$$A(S_1) / A(P_2) = 2.383(2)$$

→ depends on nuclear spin assumed in fitting procedure

◆ g-factors-> deduced from the determined magnetic moment

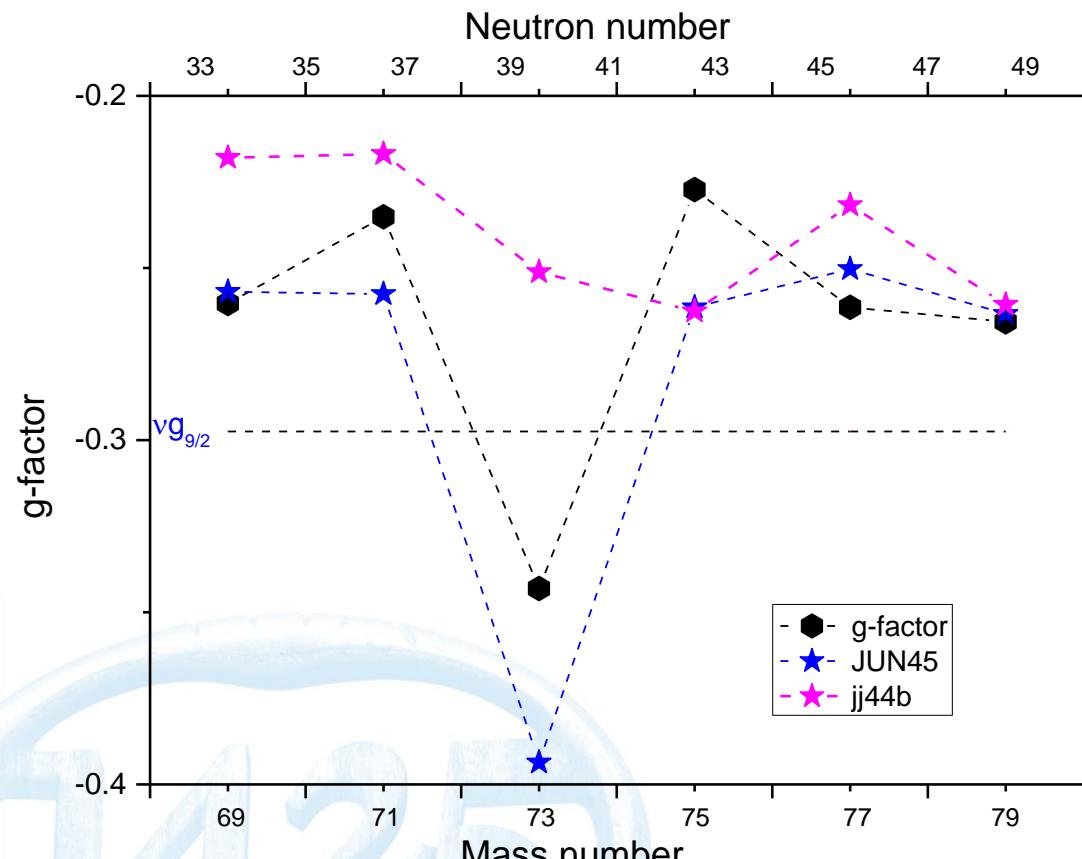
Information on the orbit occupied by unpaired neutron(s):
 compare data to effective single particle g-factors ($0.7 g_s^{\text{free}}$)

..... Effective single-particle g factor



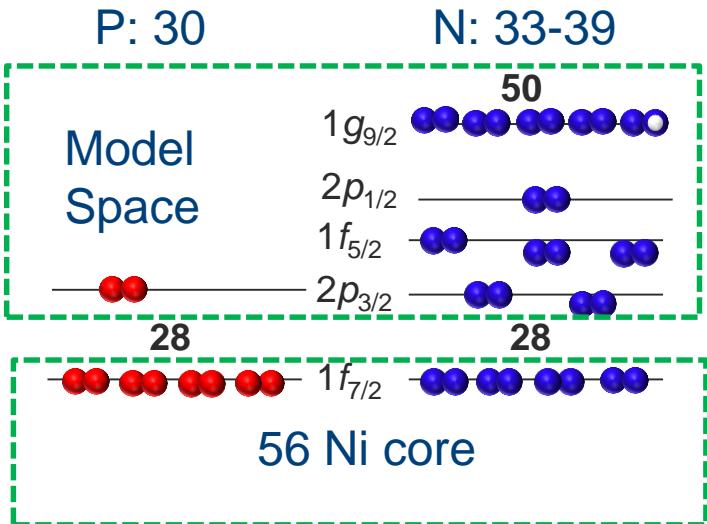
- The 3/2- gs (^{63}Zn) with mixed configuration
- The 5/2- gs ($^{63,65}\text{Zn}$) have unpaired particles in $f_{5/2}$ orbit
- The 1/2- gs/isomer from a single neutron in $p_{1/2}$ orbit
- Positive parity for the gs/isomer in $^{69-79}\text{Zn}$ has unpaired particles/holes in $vg_{9/2}$
 -> 5/2+ isomer in ^{73}Zn has some mixing !
- Confirm the positive parity of the $\frac{1}{2}$ isomer in ^{79}Zn confirmed
 -> only $vs_{1/2}$ has strong negative g-factor
 -> some mixing with $vd_{5/2}$ configuration

g-factors: states with dominant $\nu(g_{9/2})^n$ configuration



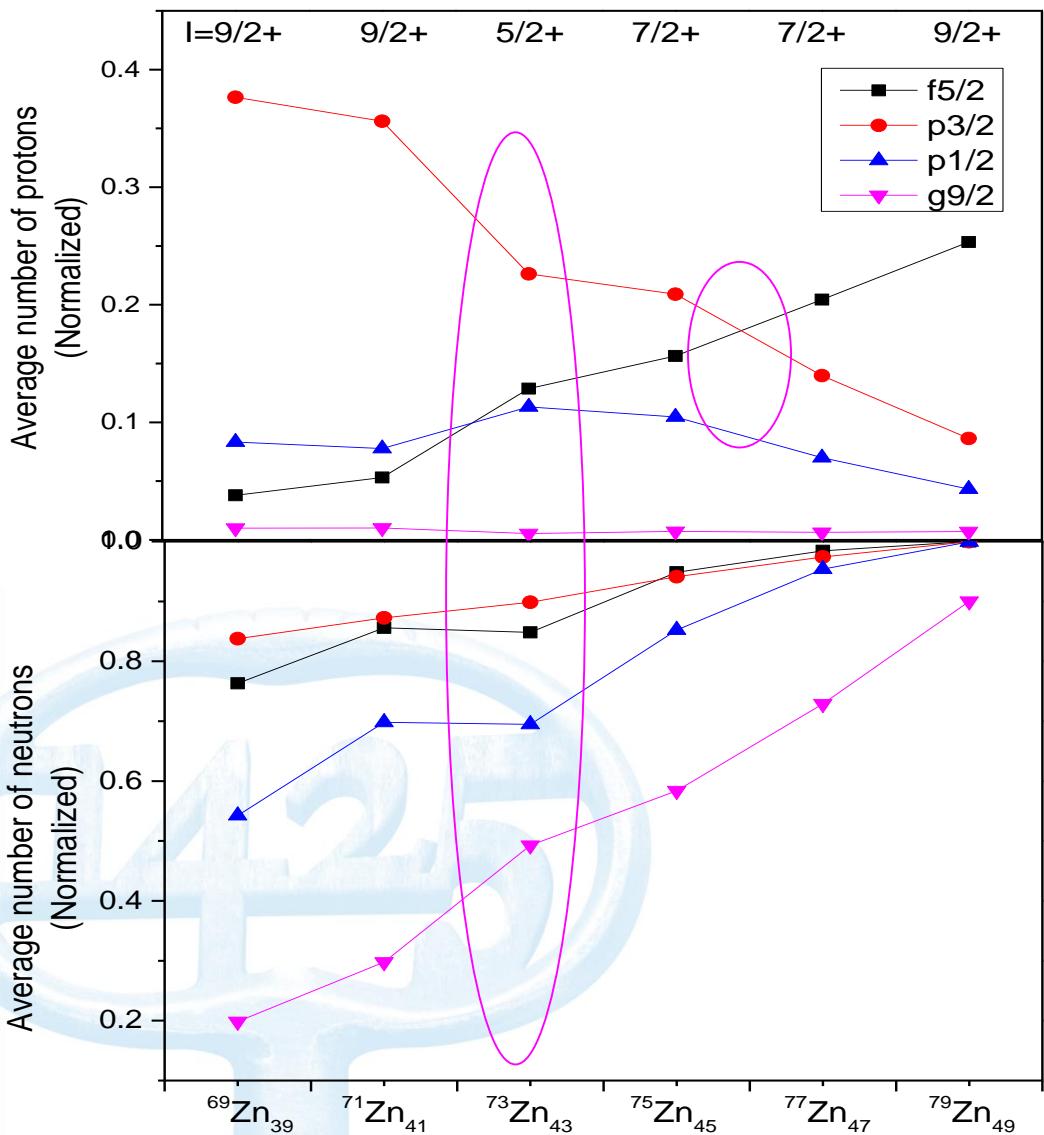
- the $5/2^-$ state in ^{73}Zn has more mixing !
- this is reproduced by the JUN45 interaction

JUN45/jj44b interaction



JUN45: M. Honma *et al.*, Phys. Rev. C **80**, 064323 (2009).
 jj44b: D. Verney *et al.*, Phys. Rev. C **76**, 054312 (2007).

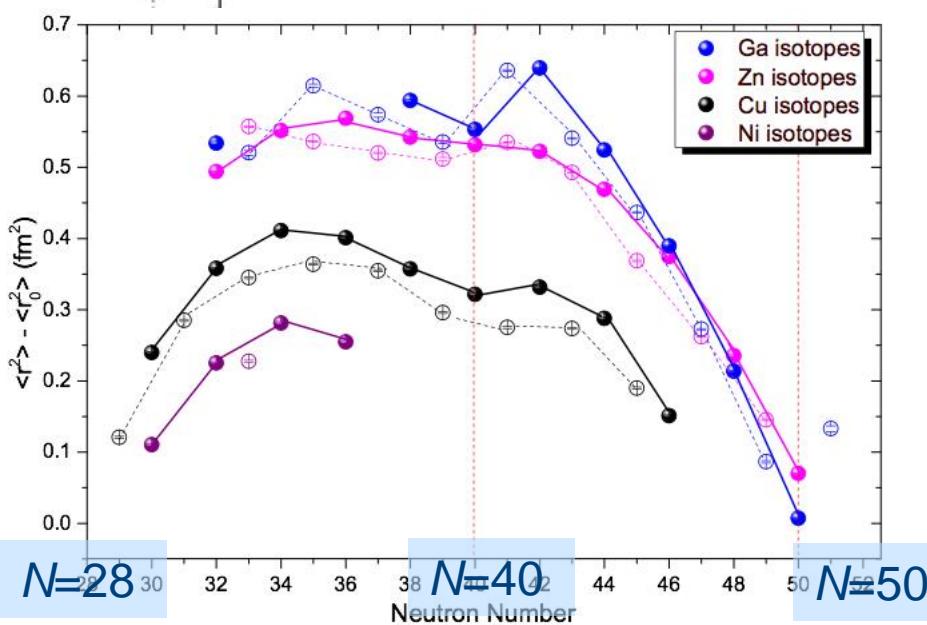
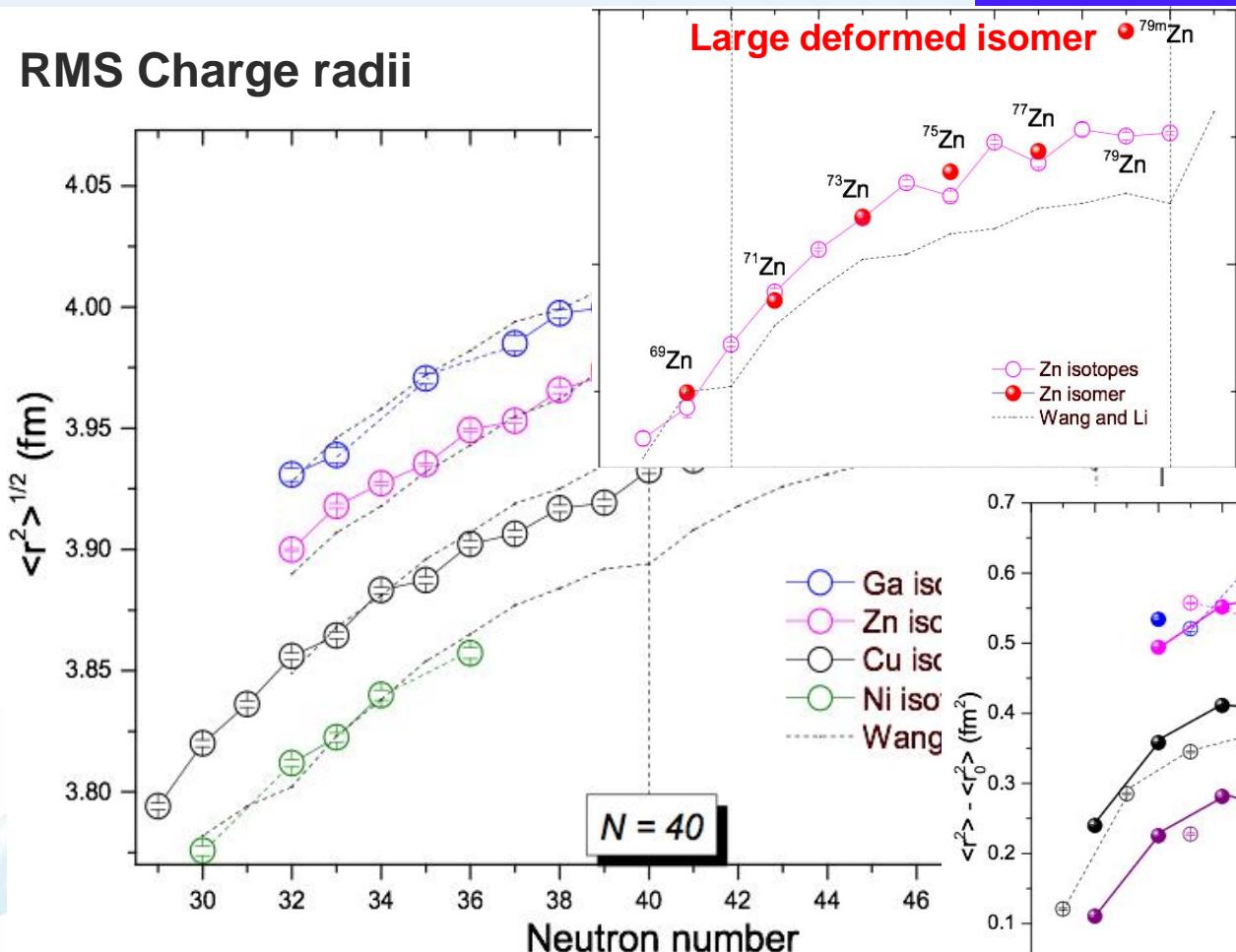
Proton/neutron occupation numbers in the positive parity high-spin levels calculated by JUN45



- As neutrons are added to the $g_{9/2}$, the occupation number in $\pi f_{5/2}$ increase but decrease in $\pi p_{3/2}$.
- An inversion of occupation occurs in $\pi p_{3/2} / \pi f_{5/2}$ around $^{76}\text{Zn}_{46}$ ($Z=30$), which is consistent with **the inversion of the proton orbit due to tensor effect**. It is known to occur in $^{75}\text{Cu}_{46}$ ($Z = 29$) and $^{79}\text{Ga}_{48}$ ($Z = 31$).
- A kink appear around 73Zn , suggesting an increase of configuration mixing for the $5/2+$ isomer in 73Zn

P-h excitations across $N=40$ in $^{69-77}\text{Zn}$

RMS Charge radii



M. L. Bissell *et al.*, "to be submitted," (2015)

T. J. Procter *et al.*, Phys. Rev. C **86**, 034329 (2012).

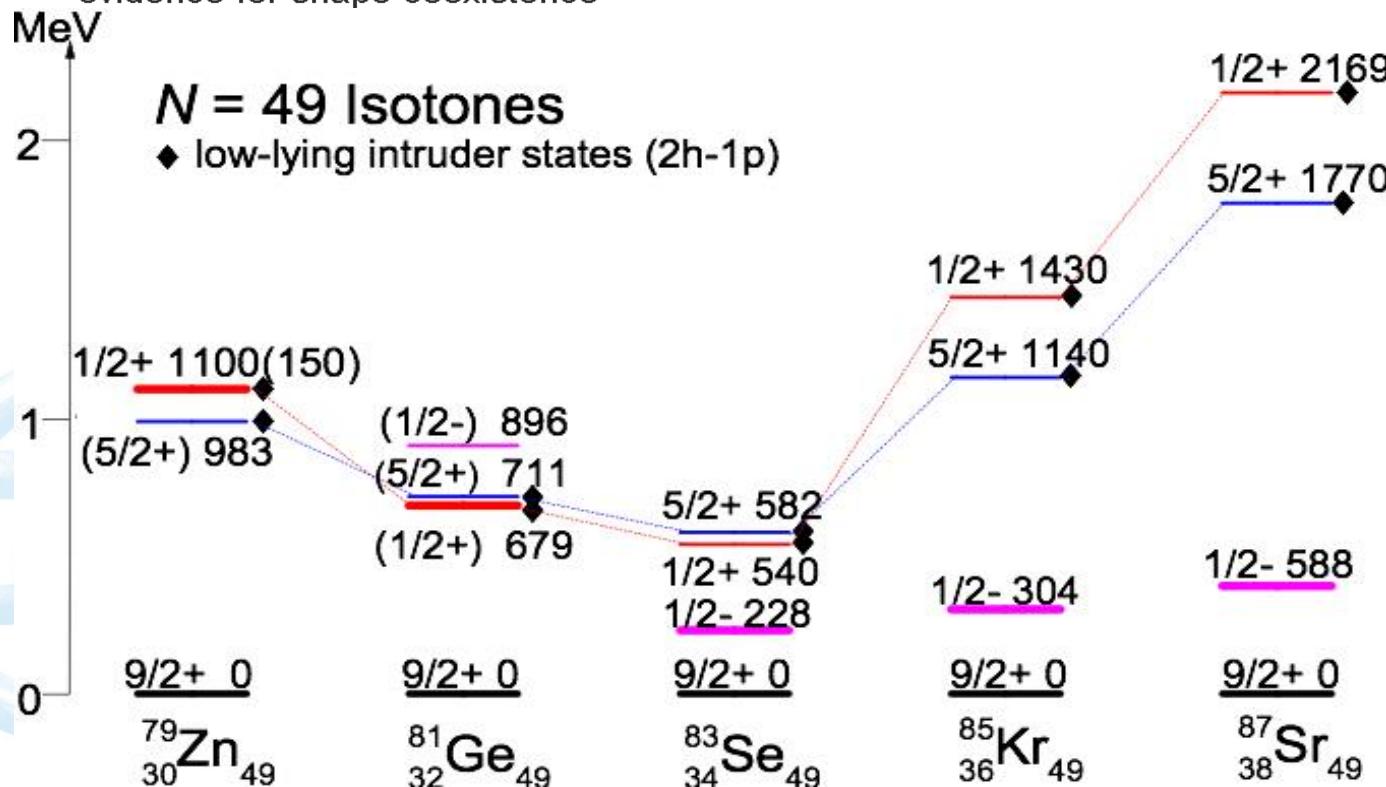
N. Wang and T. Li, Phys. Rev. C **88**, 011301 (2013).

I. Angelia and K. Marinova, At. Data Nucl. Data Tables **99**, 69 (2013).

- a weak $N=40$ sub-shell effect
- a clearly $N=50$ shell effect

Highlight points on the $\frac{1}{2}^+$ isomer in ^{79}Zn

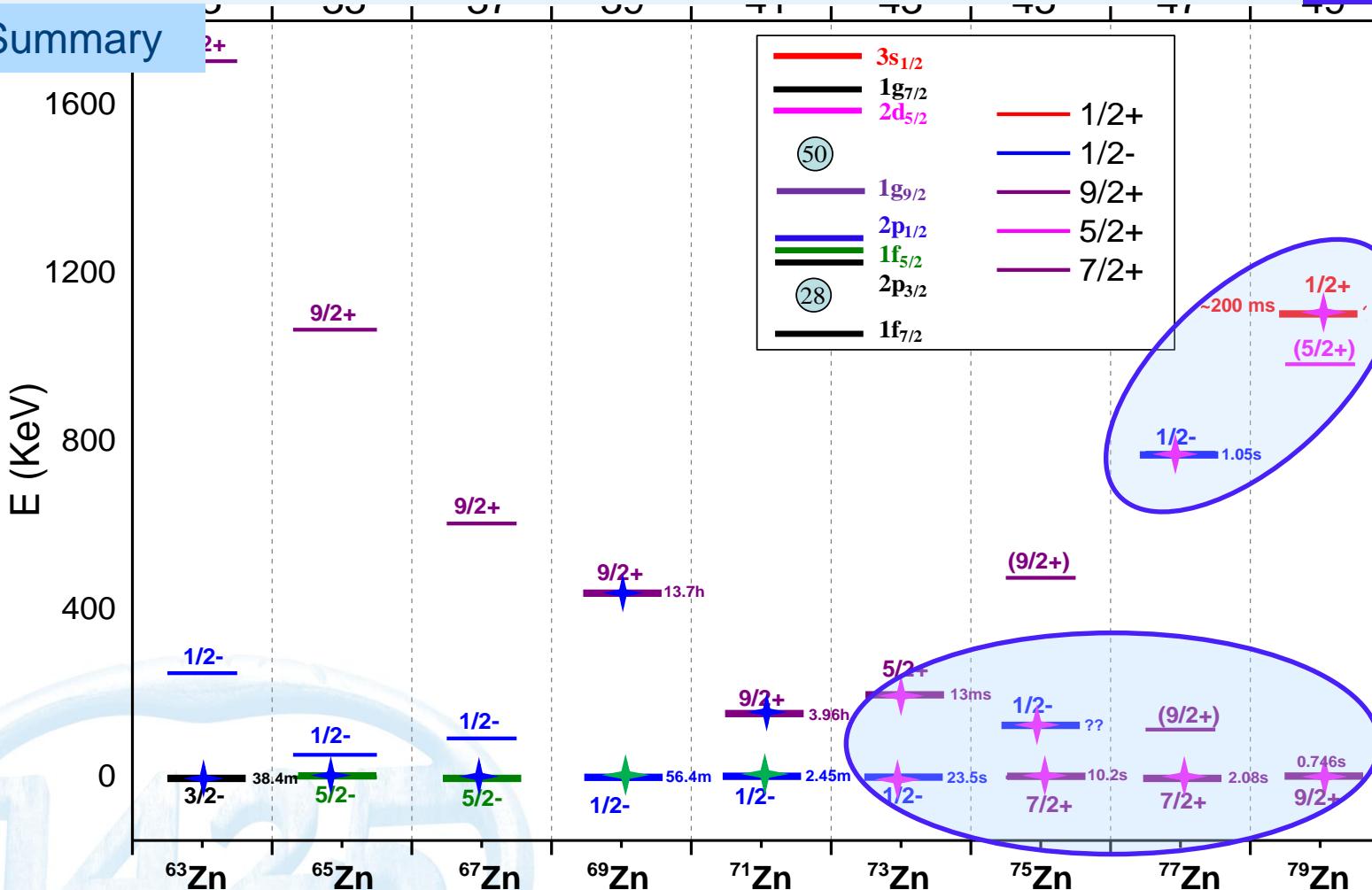
- Long-lived nature of $\frac{1}{2}^+$ isomer
- g-factor: the 2h-1p intruder $\frac{1}{2}^+$ isomer with $\nu(1g_{9/2}^{-2} 2s_{1/2})[1/2^+]$ configuration
->mixing with $\nu(1g_{9/2}^{-2} 2d_{5/2})[1/2^+]$ is not excluded
- Large isomer shift gives a large deformation on the isomer
-> evidence for shape coexistence



Data are taken from NNDC

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Summary



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Thanks for your attention!

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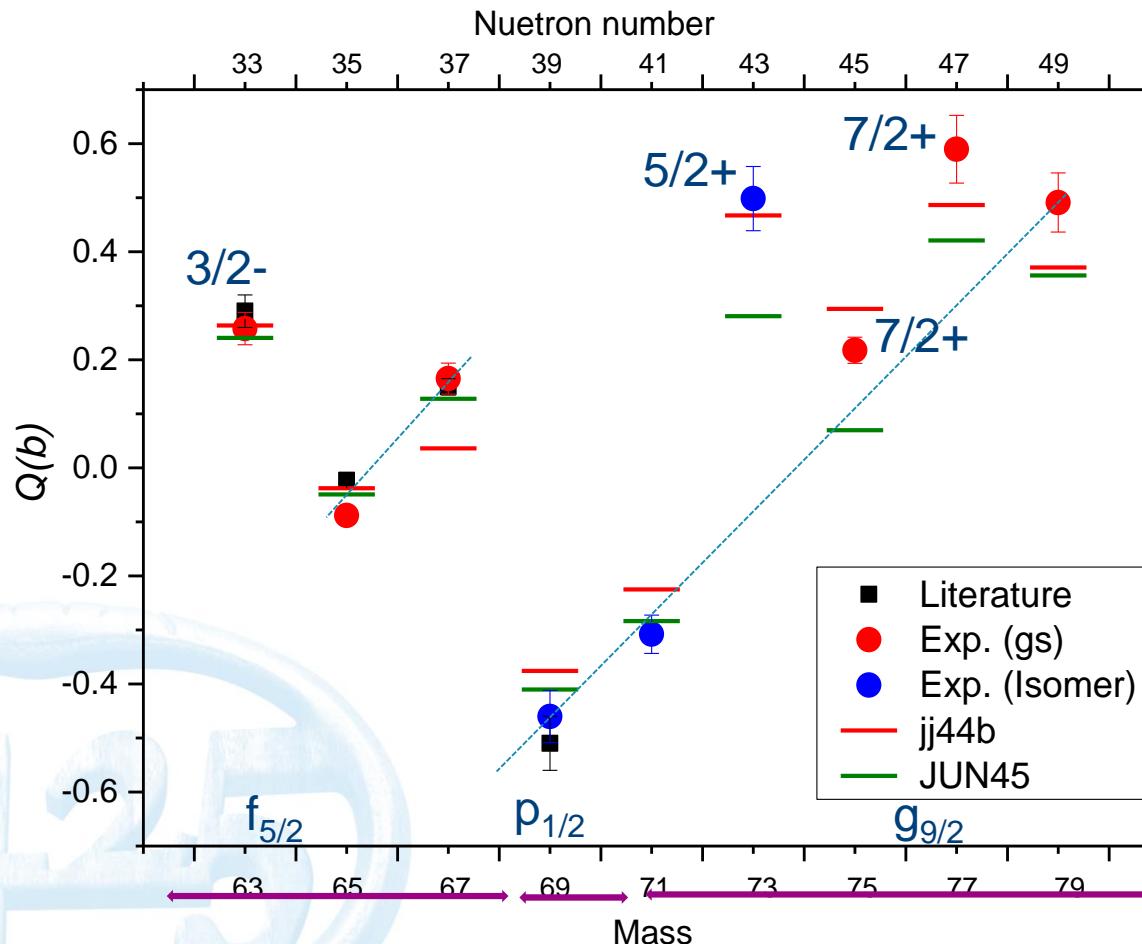
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Quadrupole moment

-> (Agree with the shell model calculation with jj44b/JUN45)

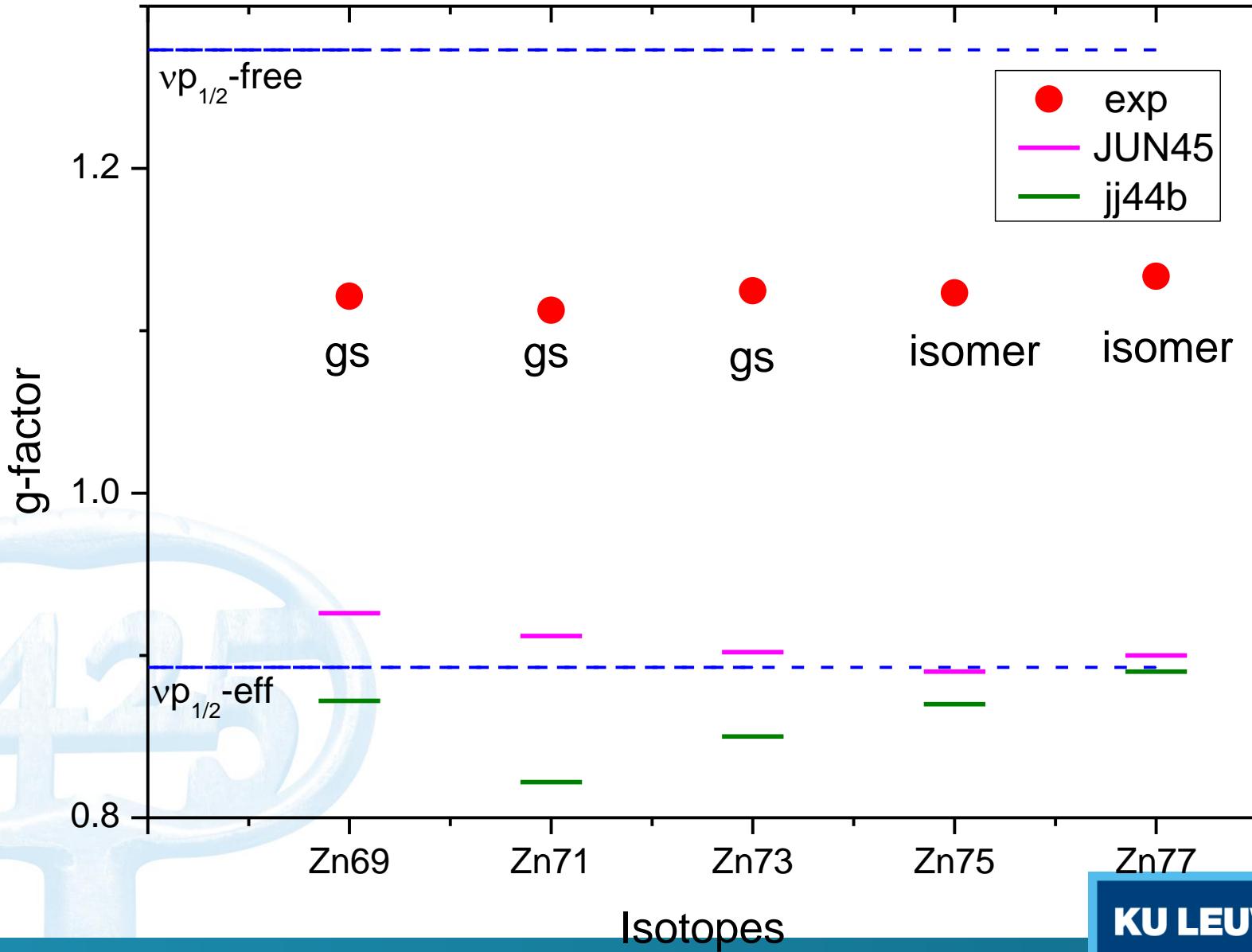


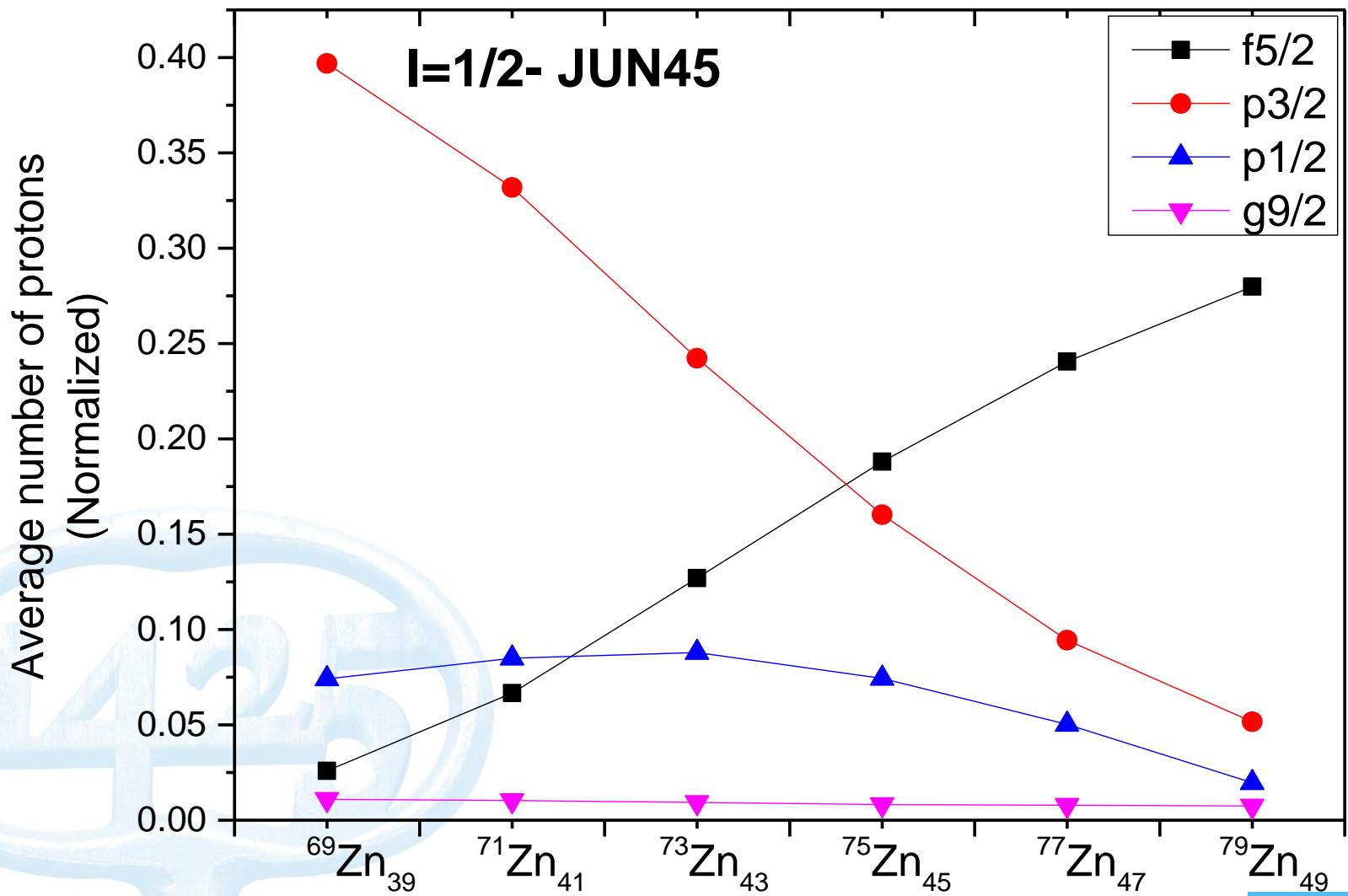
N.S. Laulainen et al., Phys. Rev. **177**, 1606(1969)

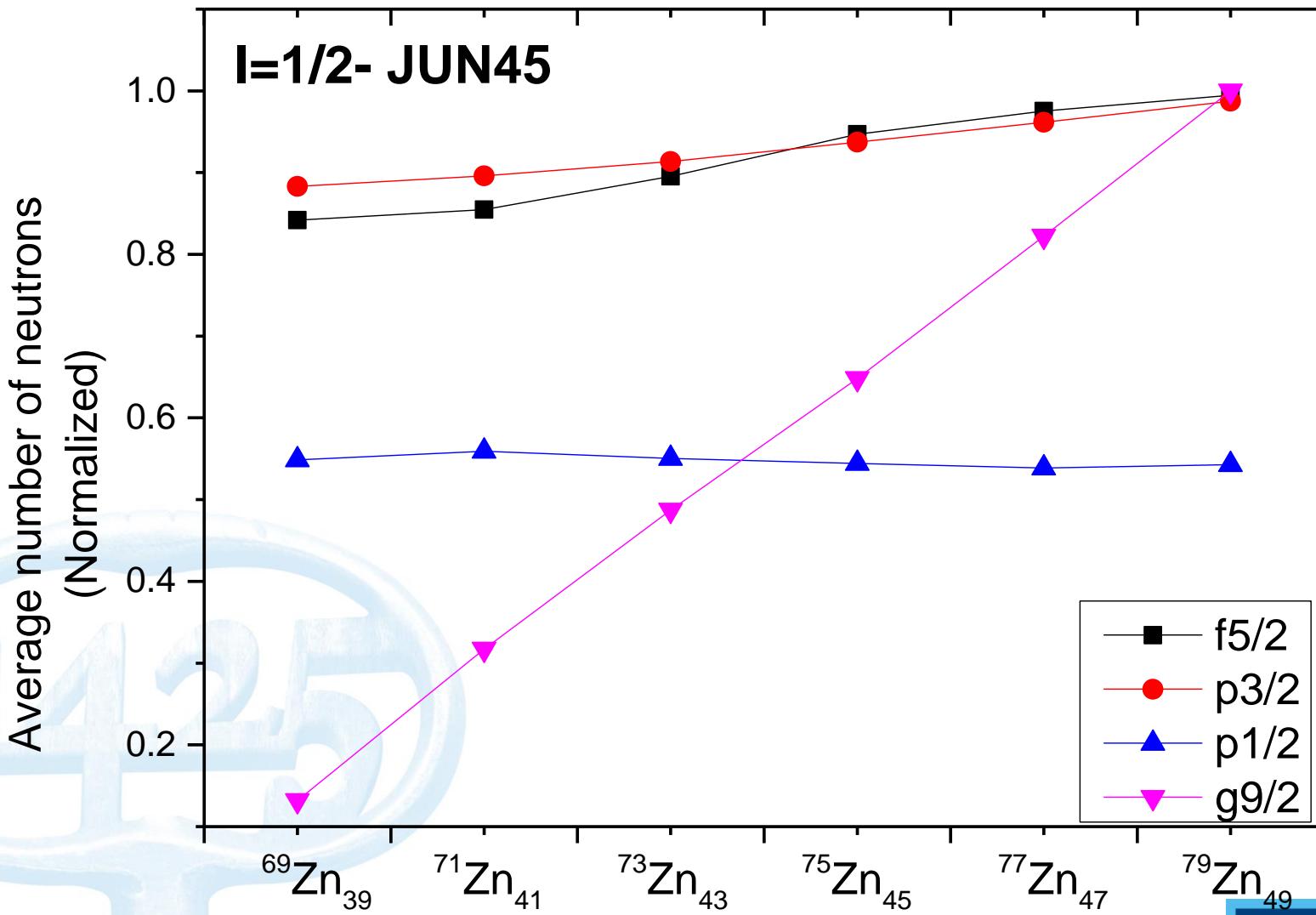
F.W. Byron et al., Phys. Rev. **134**, A47(1964)

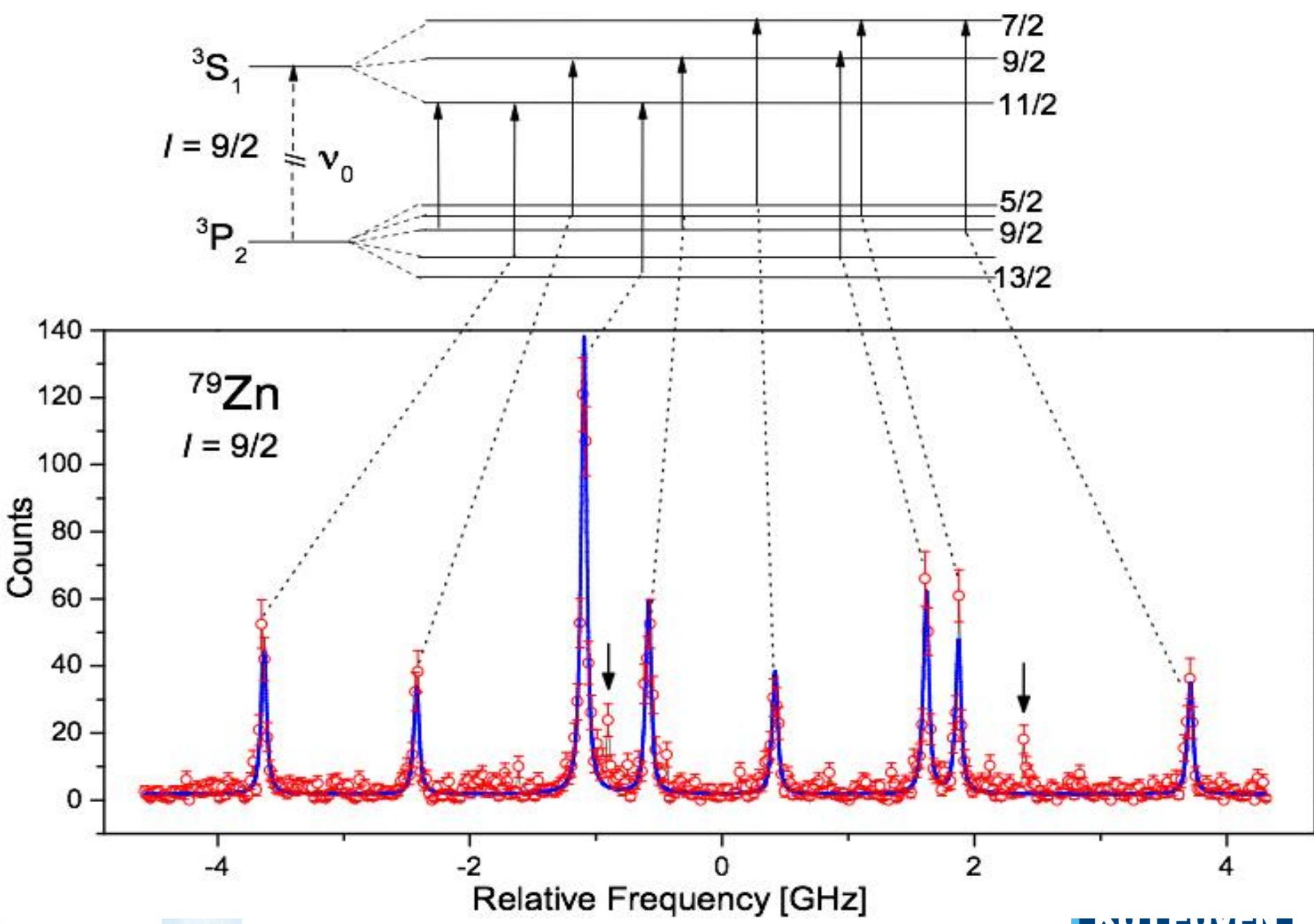
F.W. Byron et al., Phys. Rev. **134**, A47(1964)

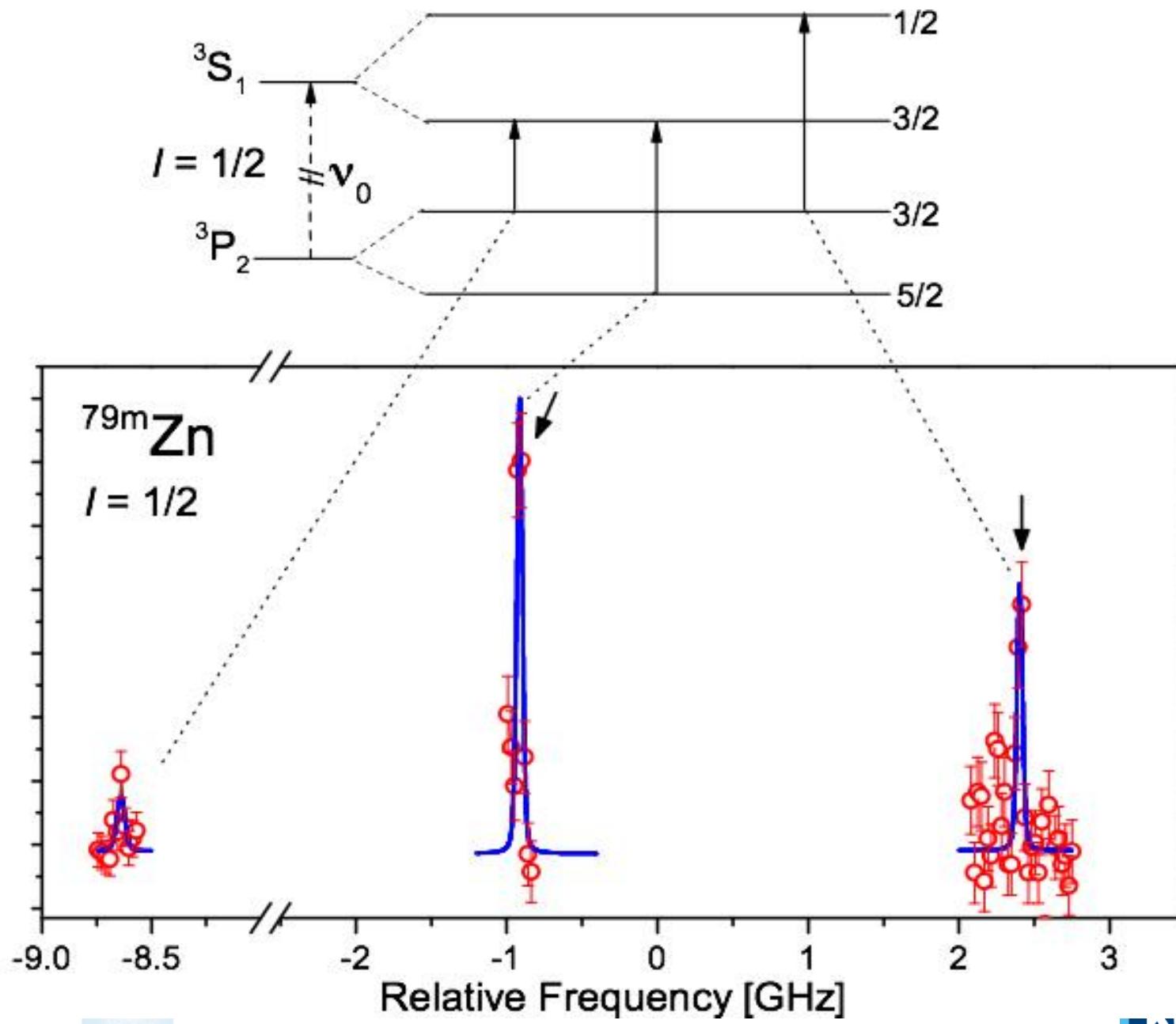
D. Oertel et al., Z. Phys. A **310**, 233-241 (1983)











Weisskopf estimate

