Structure of Potassium and Calcium isotopes studied by Collinear Laser Spectroscopy

Gerda Neyens

ISOLDE WORKSHOP 2014

Belgian Research Initiative on Exotic nulcei

KU LEUVEN

Collinear laser spectroscopy

Motivation to study K and Ca region

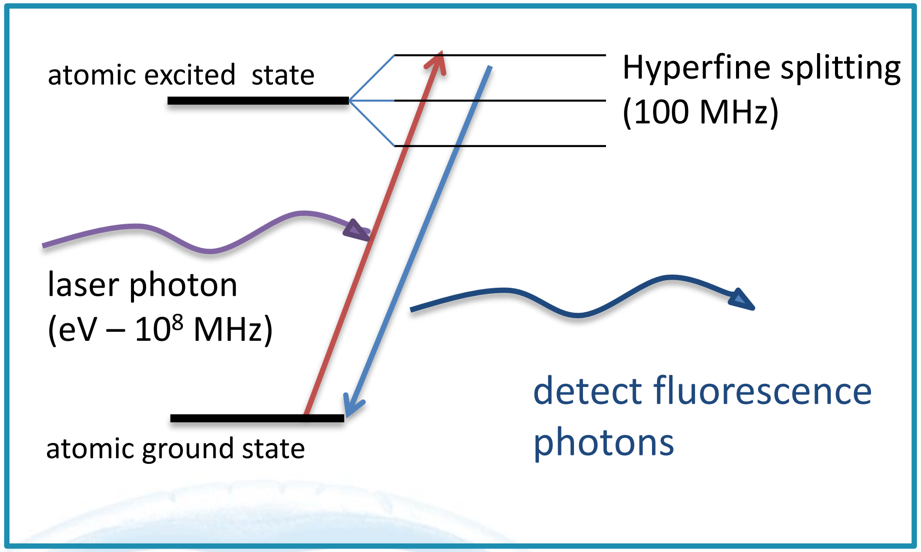
Selected results for K isotopes

Selected results for Ca isotopes

Conclusions and outlook

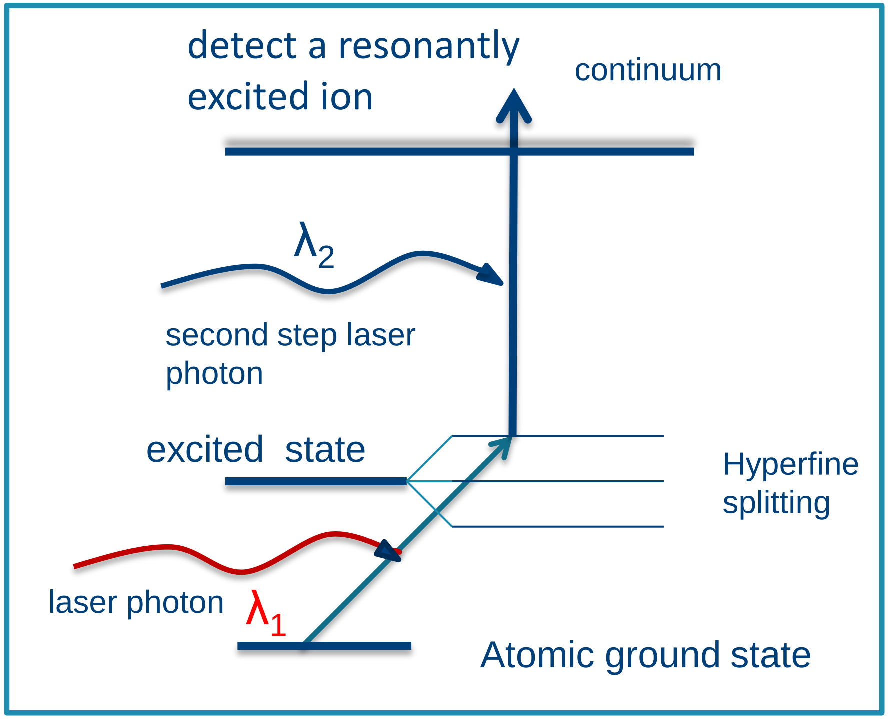
Collinear laser spectroscopy

at COLLAPS



- low background
  - bunched beams
  - new detection system
- high resolution (~ 50 MHz)
- need about 10.000 ions/s from ISOLDE
- atoms or ions

at CRIS



- very low background
- high resolution (~ 30 MHz)
  (see poster 36 by R. De Groote)
- need about 100 ions/s from ISOLDE
- atoms (and ions)

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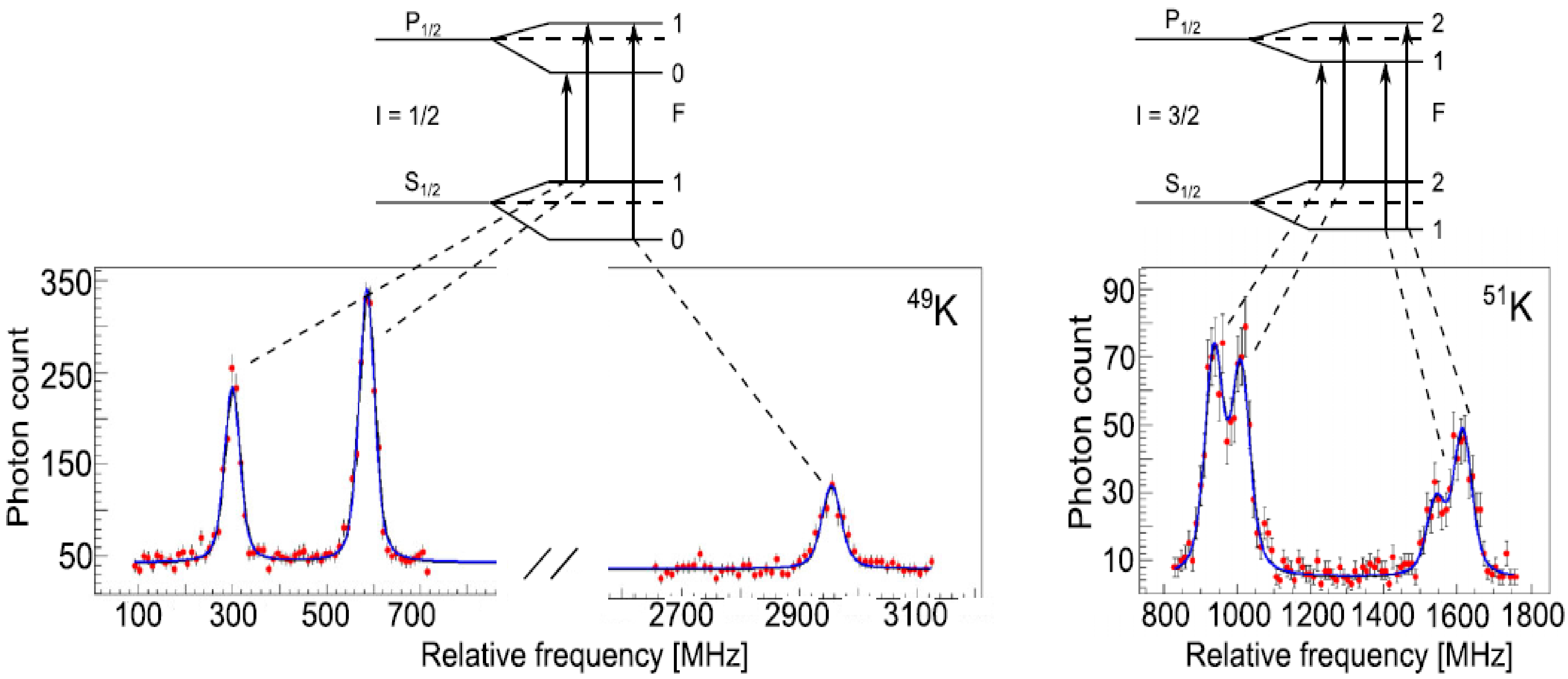
Collinear laser spectroscopy

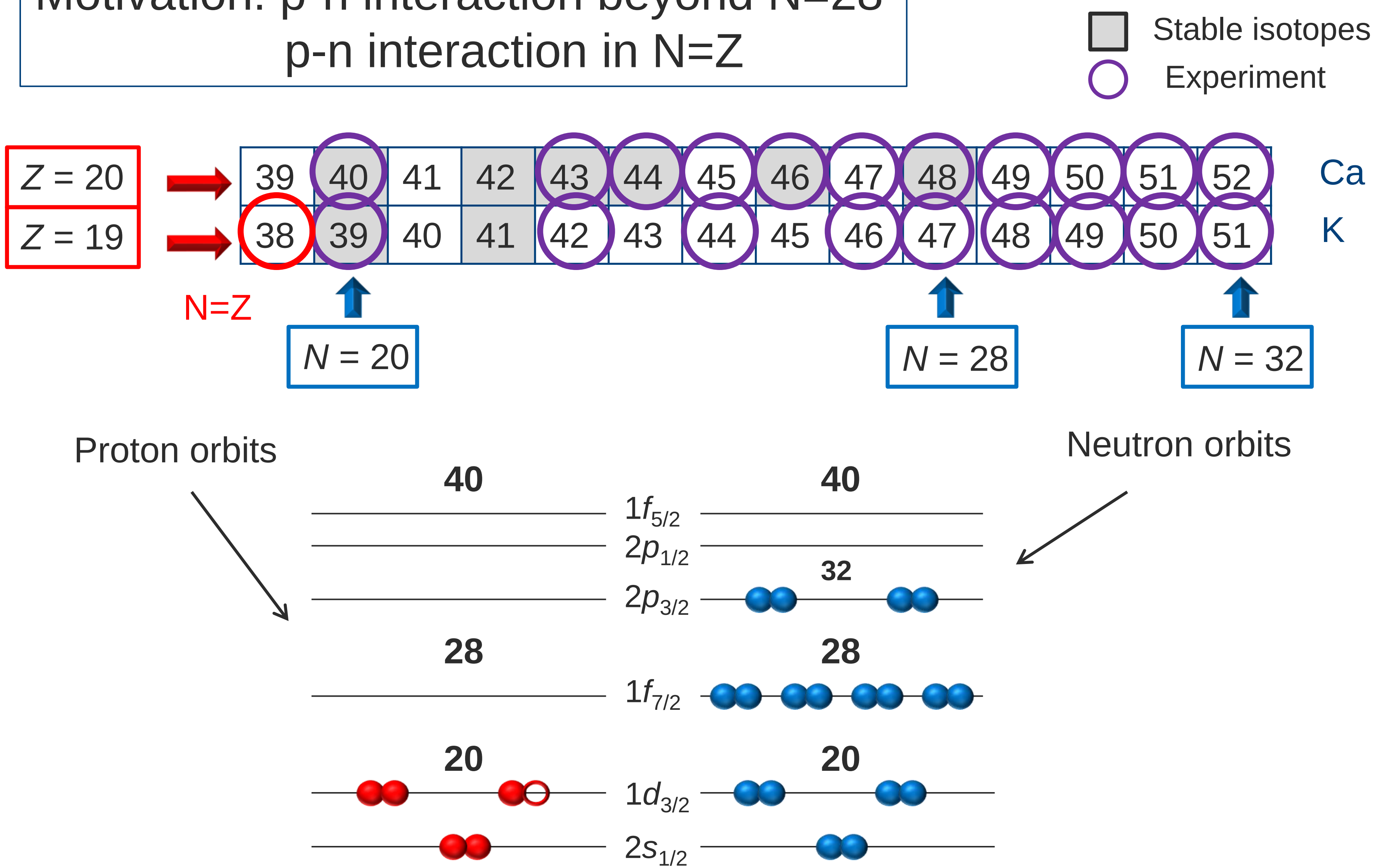
Measure in a model-independent way 4 properties of an exotic isotope/isomer:

- the nuclear spin I
- the magnetic dipole moment μ
- the electric quadrupole moment Q (if electronic and nuclear spin J,I>1/2)
- the isotope shift → nuclear charge radius

by resonant excitation of hyperfine transitions in an atom or ion.



Motivation: p-n interaction beyond N=28
p-n interaction in N=Z



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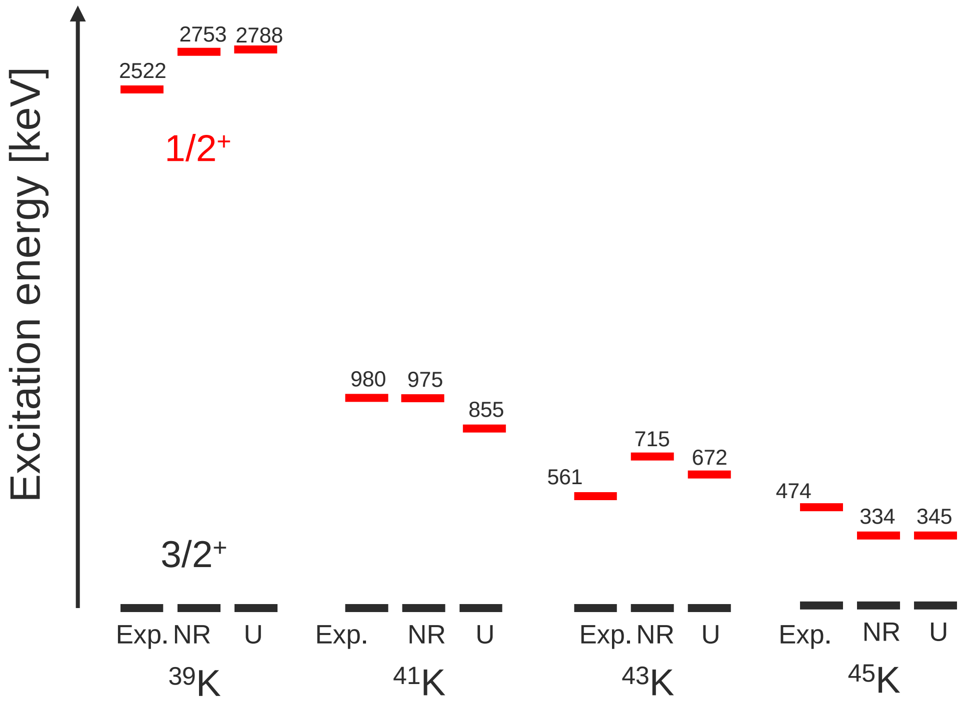
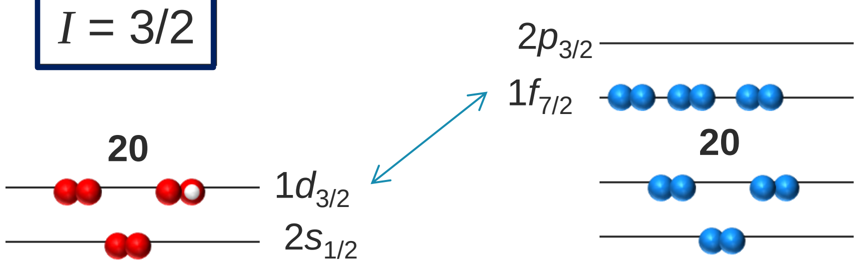
K-isotopes: sensitive to the evolution of proton orbits



Otsuka et al., PRL 87, 2001, 082502
Otsuka et al., PRL 95, 2005, 232502

$I = 3/2$



strong attractive interaction between $\pi 1d_{3/2}$ and $\nu 1f_{7/2}$
➔ gap between $\pi d_{3/2}$ and $\pi s_{1/2}$ decreases

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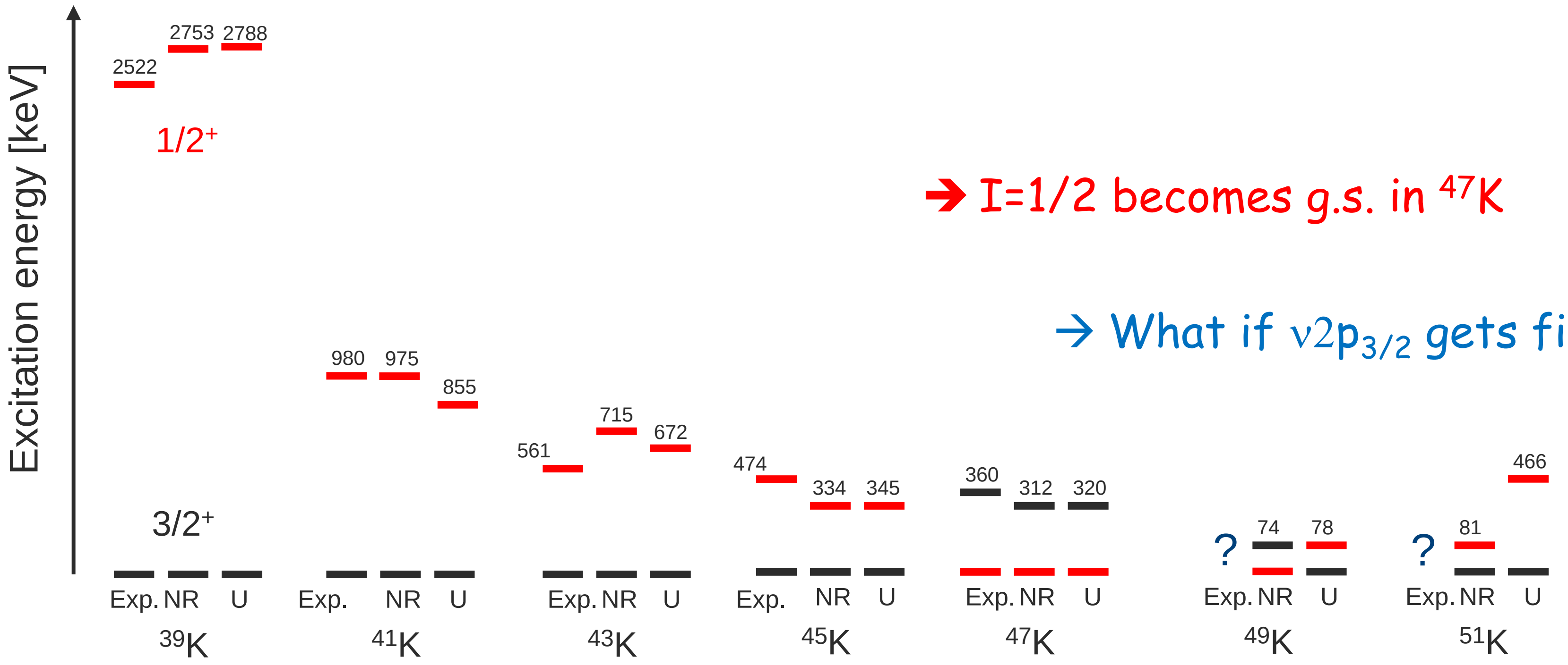
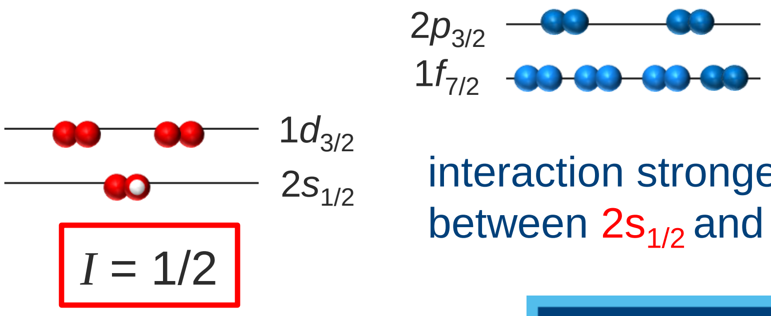
K-isotopes: sensitive to the evolution of proton orbits



→ I=1/2 becomes g.s. in ^{47}K

→ What if $\nu 2p_{3/2}$ gets filled ??



interaction strongest between $2s_{1/2}$ and $2p_{3/2}$

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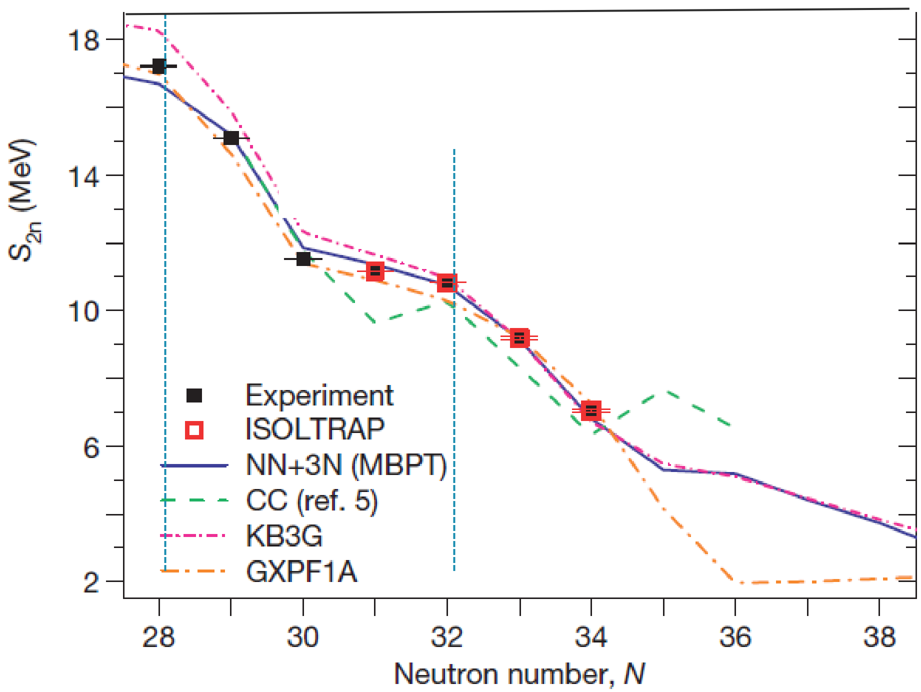
Touchard et al., PLB 108 (1982) 169

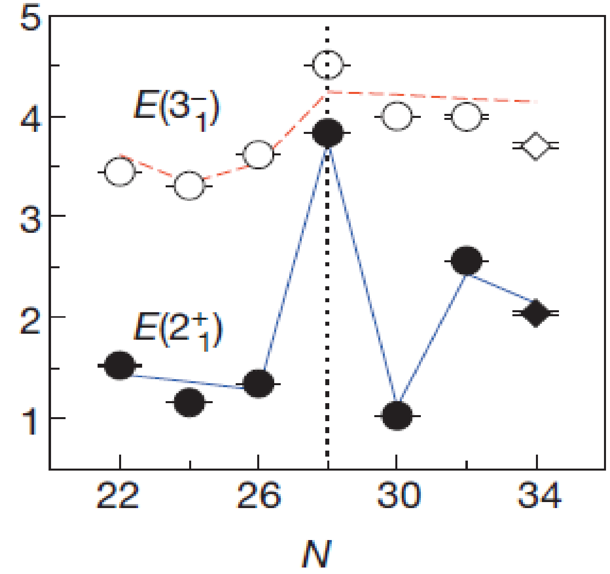
Ca-isotopes: sensitive to the neutron orbits, are N=32 and N=34 magic ?

Nature 498 (2013) 347



→ mass measurements up to N=34 establish magicity at N=32

Nature 502 (2013) 207



→ Energy of 2^+ state in even Ca establishes magicity at N=32 and N=34

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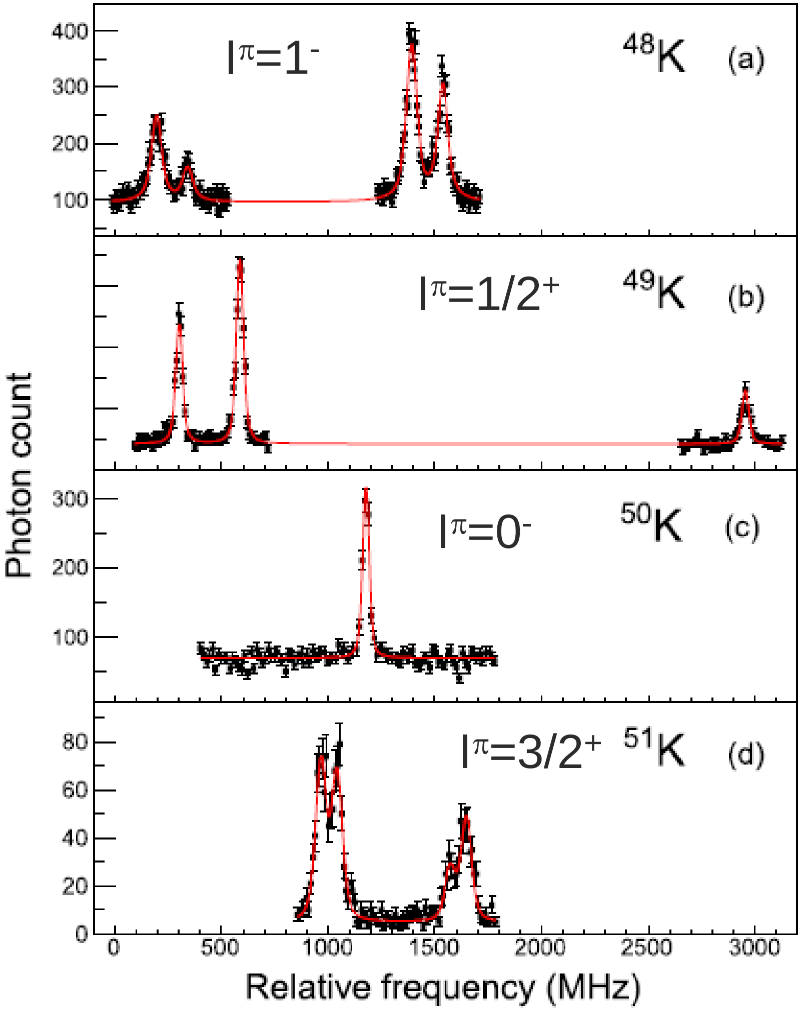
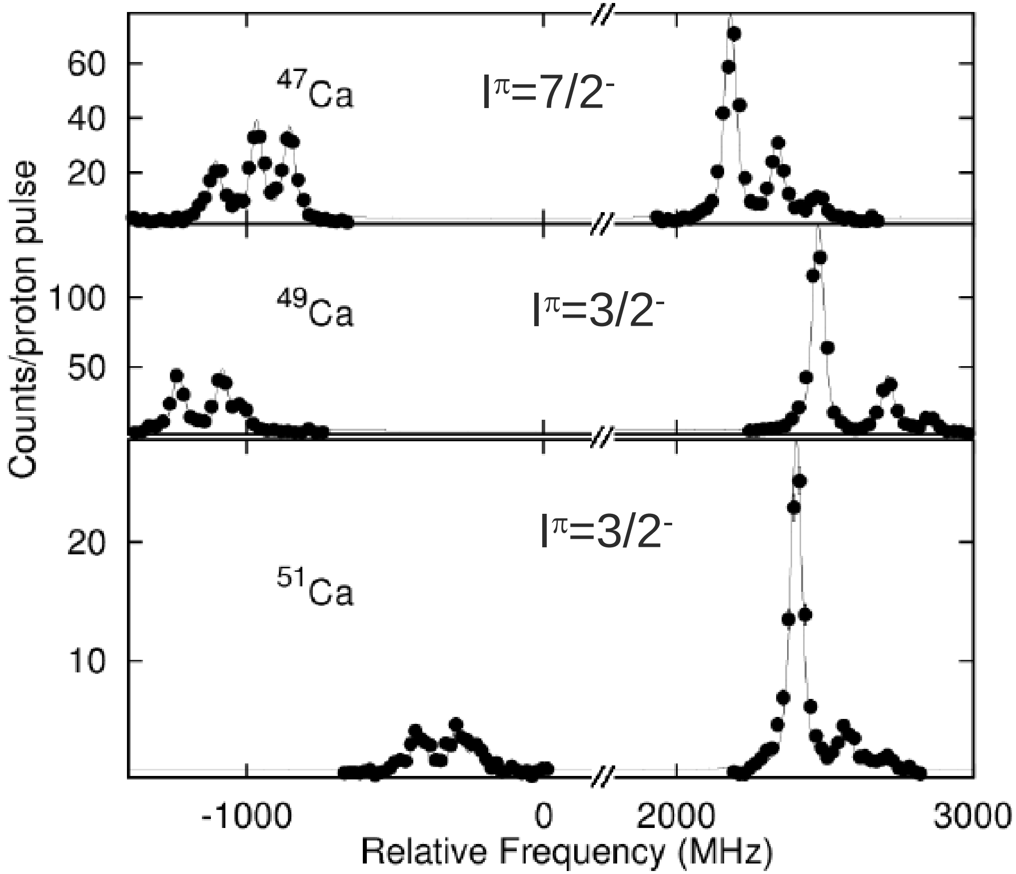
RESULTS





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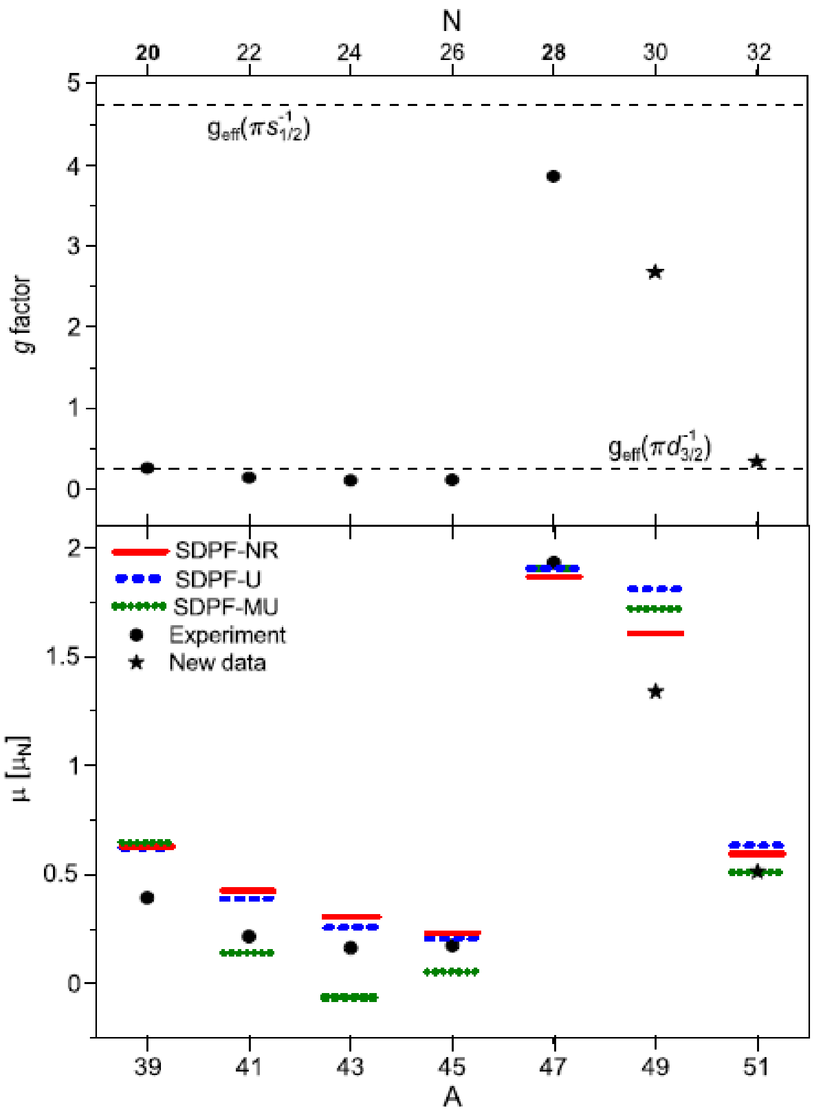
K. Kreim et al., PLB 731, 97 (2014)

R. F. Garcia Ruiz et al., submitted to PRC

Magnetic moments and g-factors of odd K



→ $^{47,\,49}$K dominated by hole in $s_{1/2}$ orbit
→ ^{49}K wave function strongly mixed with $d_{3/2}$

Calculations:

SDPF-MU, Utsuno et al., PRC 86 (2012)
SDPF-NR and SDPF-U, Nowacki, Poves, PRC79(2009)

sd for protons
pf for neutrons

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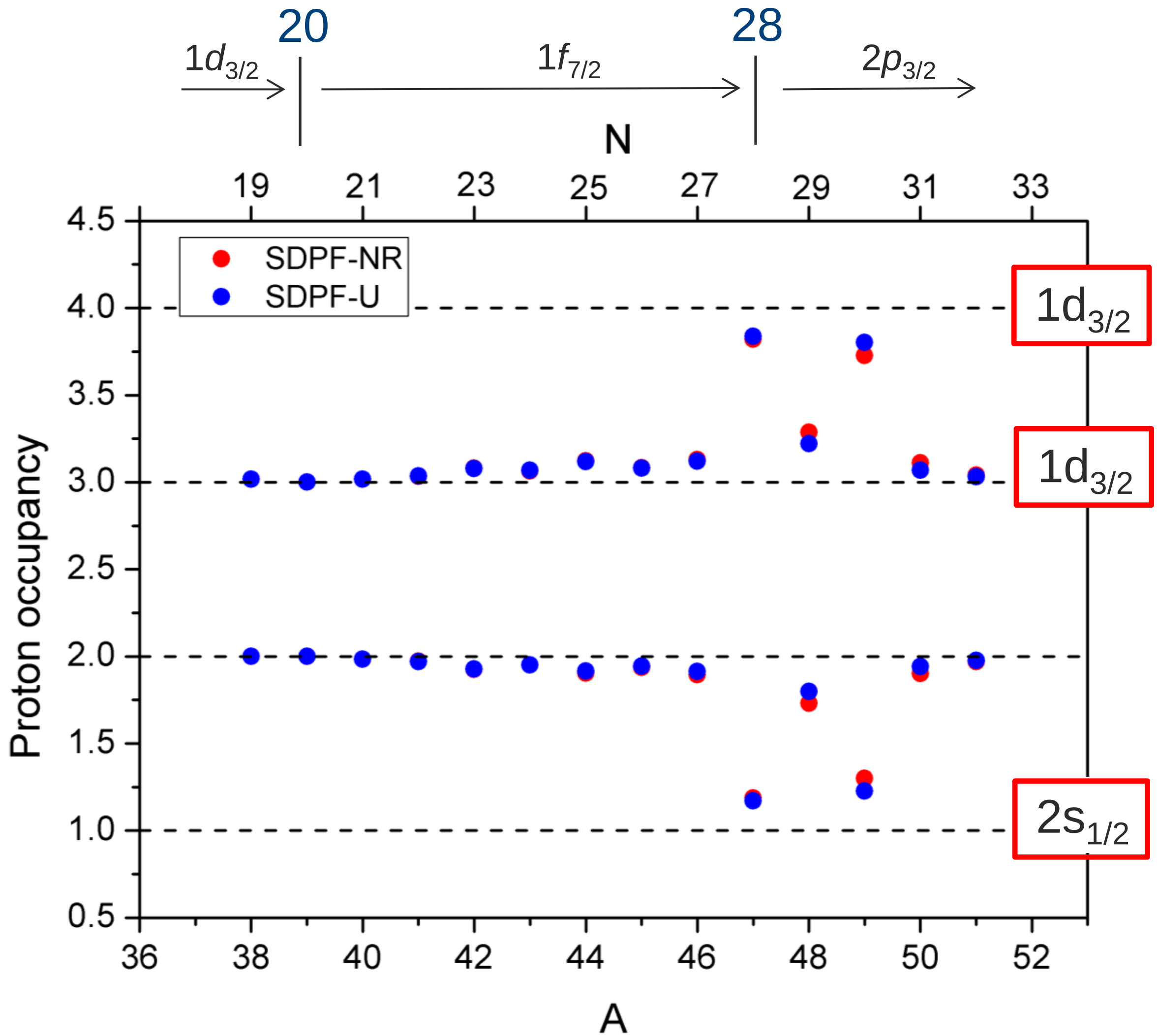
J. Papuga et al., PRL110, 172503 (2013)

Occupation of $\pi s_{1/2}$ and $\pi d_{3/2}$ as function of N



Only at N=28 and N=30 inversion of proton level occupations

fully occupied

hole in $d_{3/2}$ (normal)

hole in $s_{1/2}$ (inverted)

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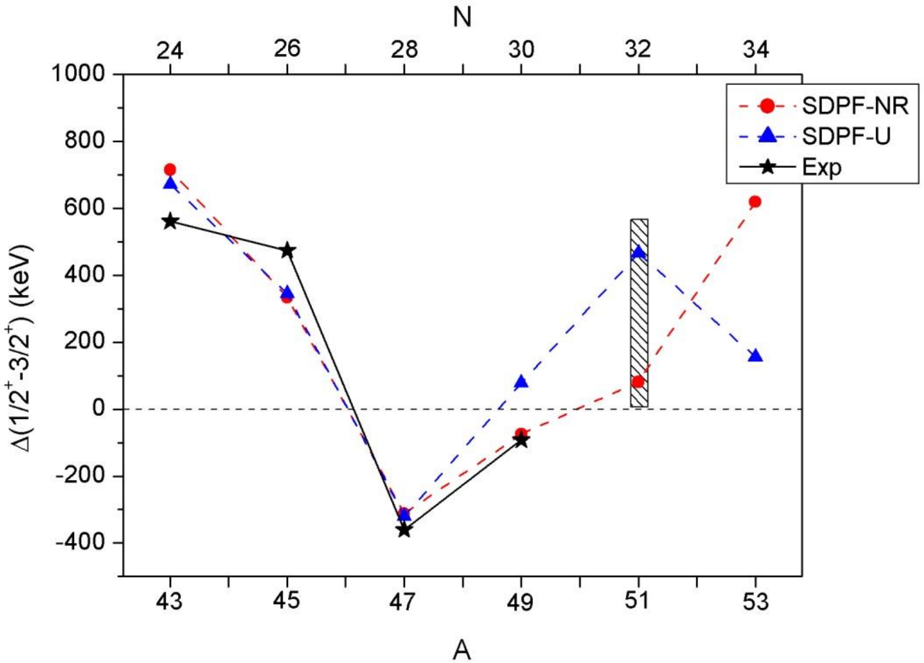
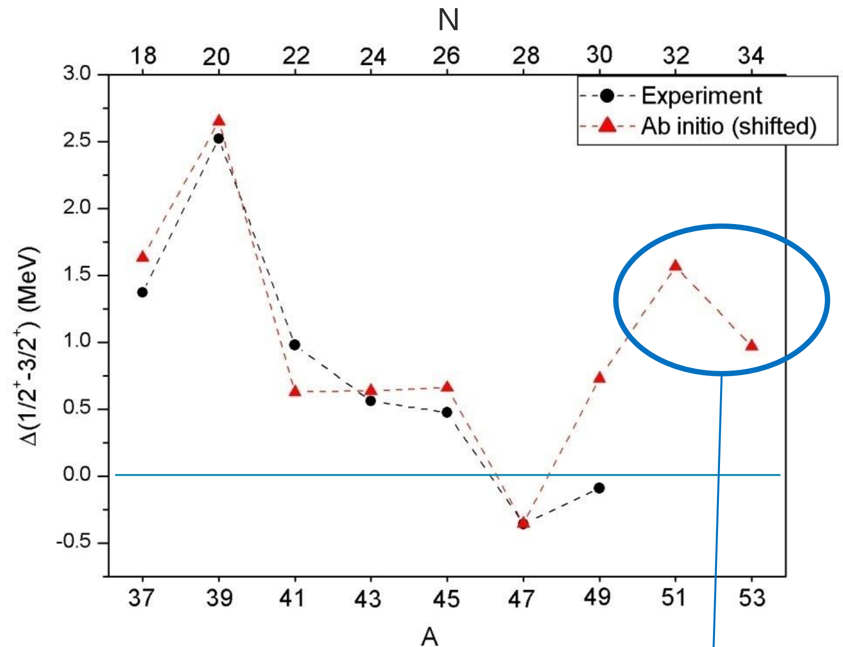
J. Papuga et al., PRC90, 034321 (2014)

Evolution of proton $s_{1/2}$-$d_{3/2}$ gap through $\Delta E(1/2^+-3/2^+)$

Model-independent determination of g.s spin of $^{49}K = ½+$, $^{51}K = 3/2+$



Shell model with effective interactions



Ab initio (Gorkov-Green`s function)

V. Somà, T. Duguet and C. Barbieri

to be measured !

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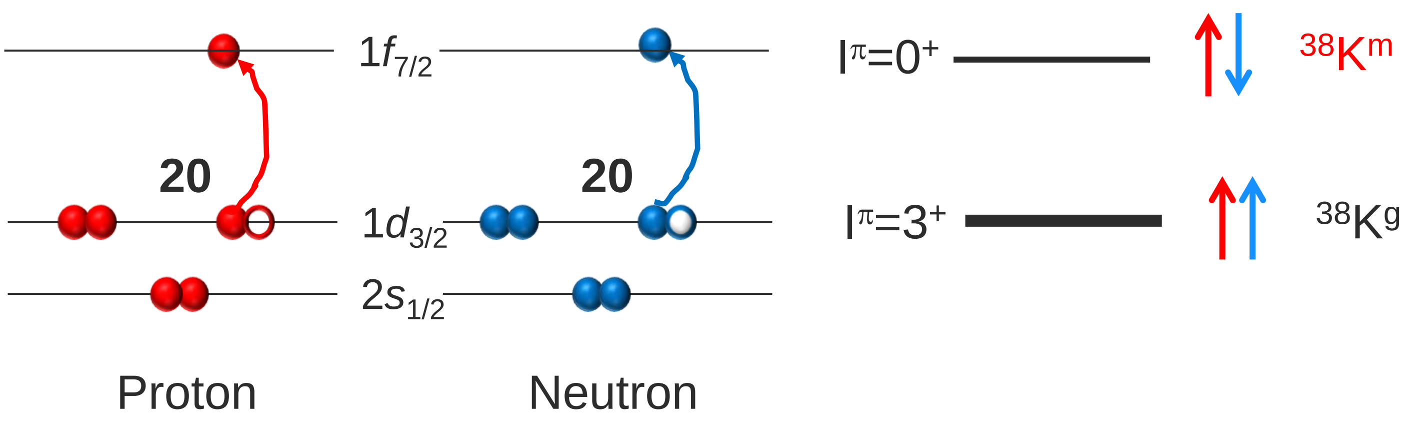
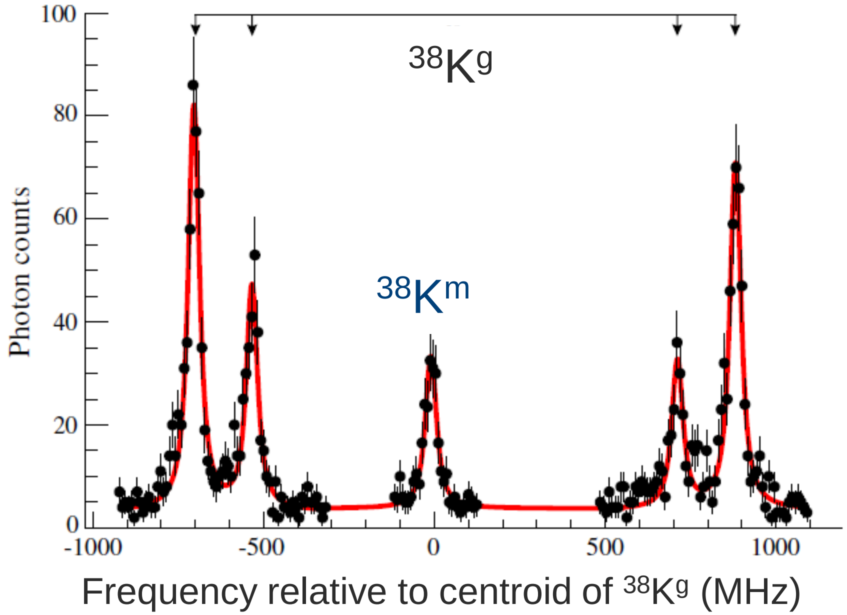
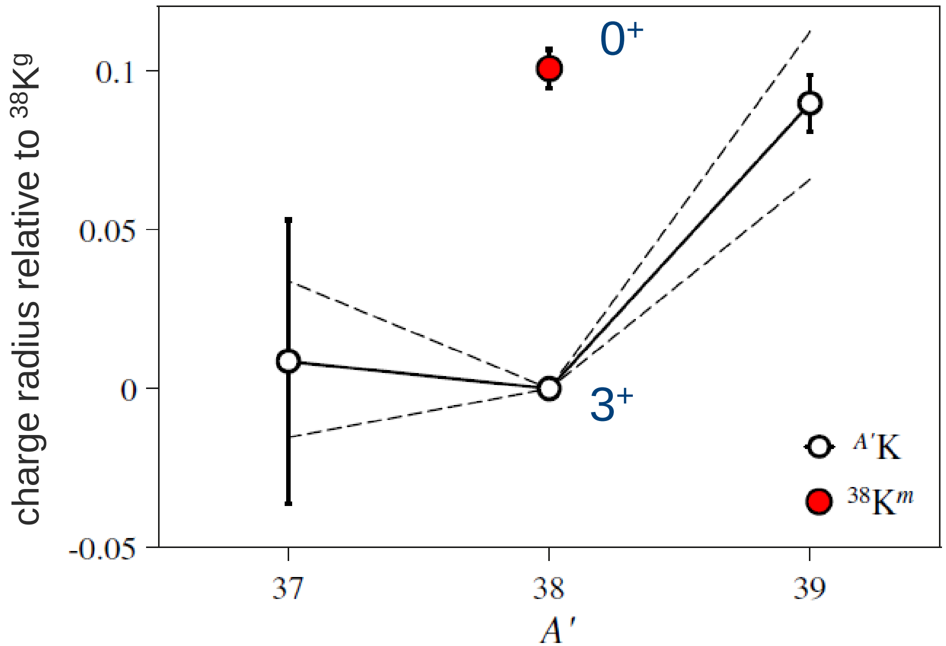
J. Papuga et al., PRC90, 034321 (2014)

Isomer shift of $^{38g,m}K$: effect of p-n correlations at N=Z



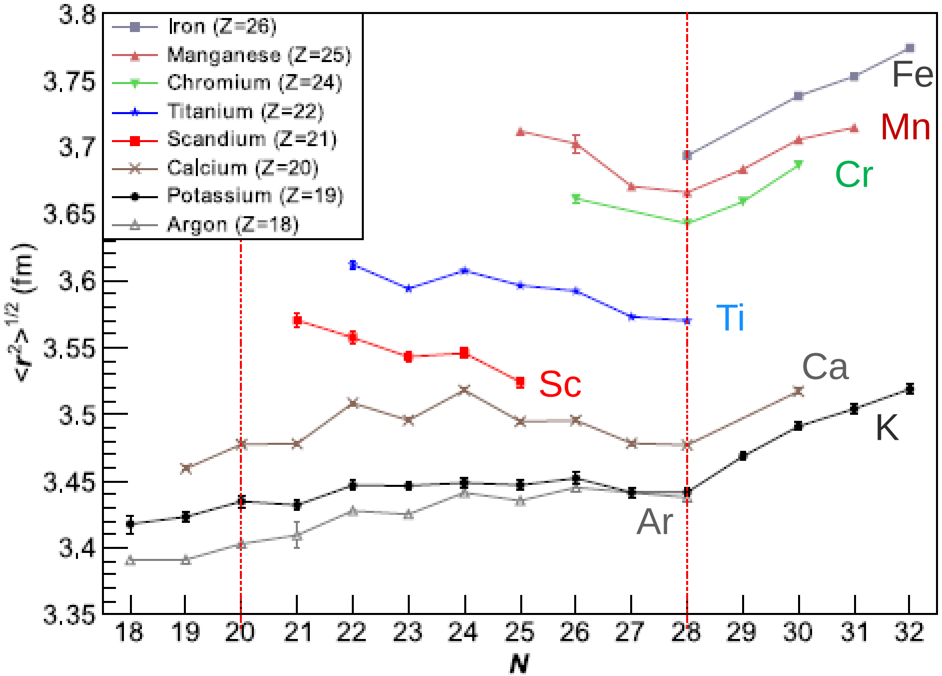
→ increased radius due to 1p-1h p and n excitations in the 0^{+} state



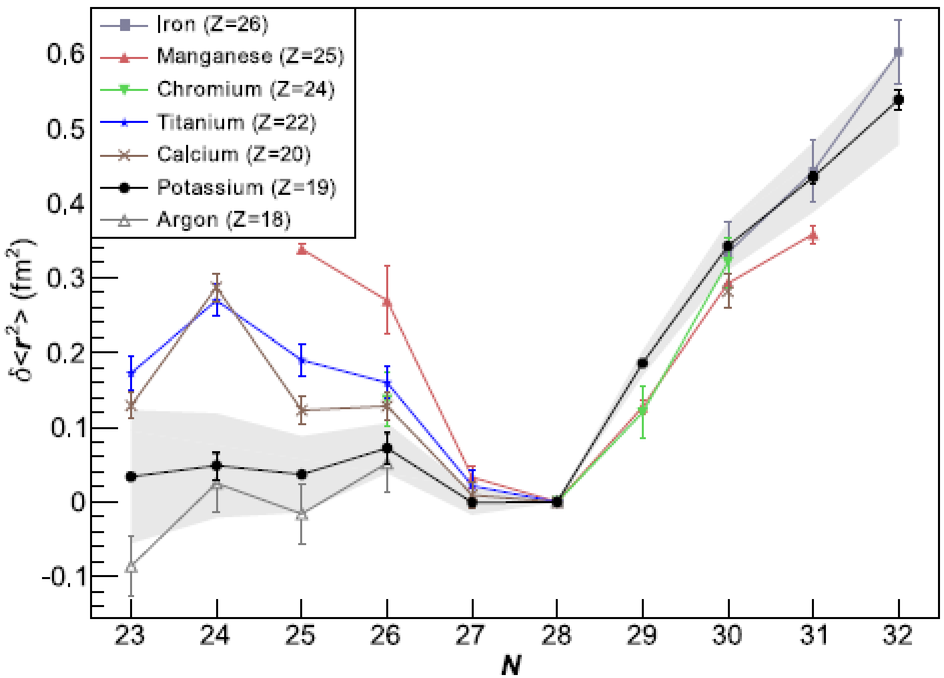


M.L. Bissell et al., PRL113 (2014) 052502

Root mean square charge radii from Z=18 to Z=26



charge radii relative to N=28



- ➔ strong Z-dependence below N=28
- ➔ little Z-dependence above N=28
- ➔ no signature of ‘magicity’ at N=32

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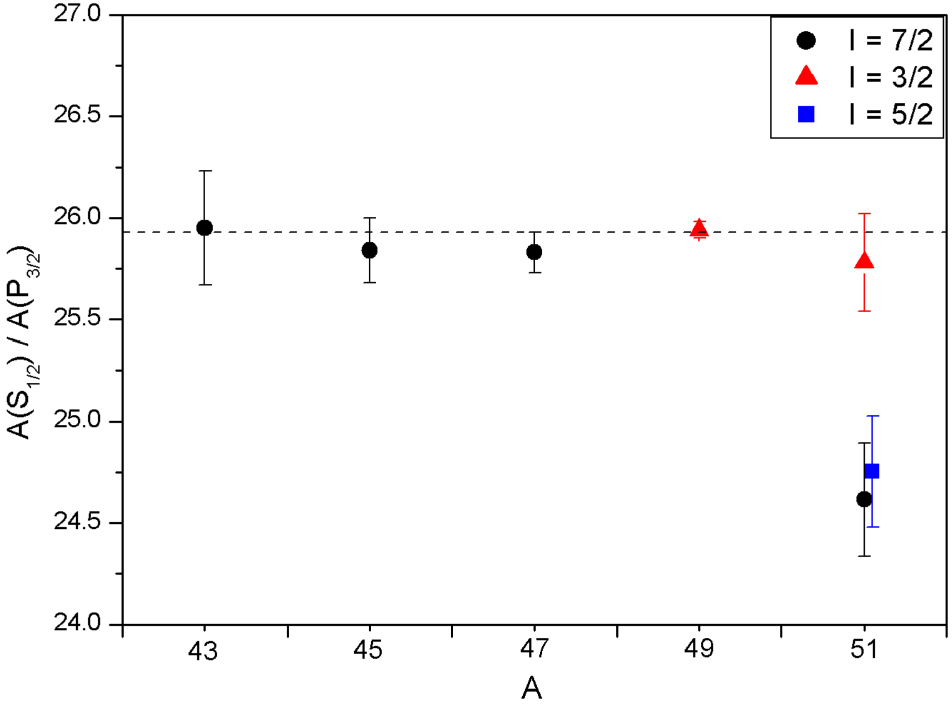
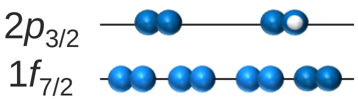
K. Kreim et al., PLB 731, 97 (2014)

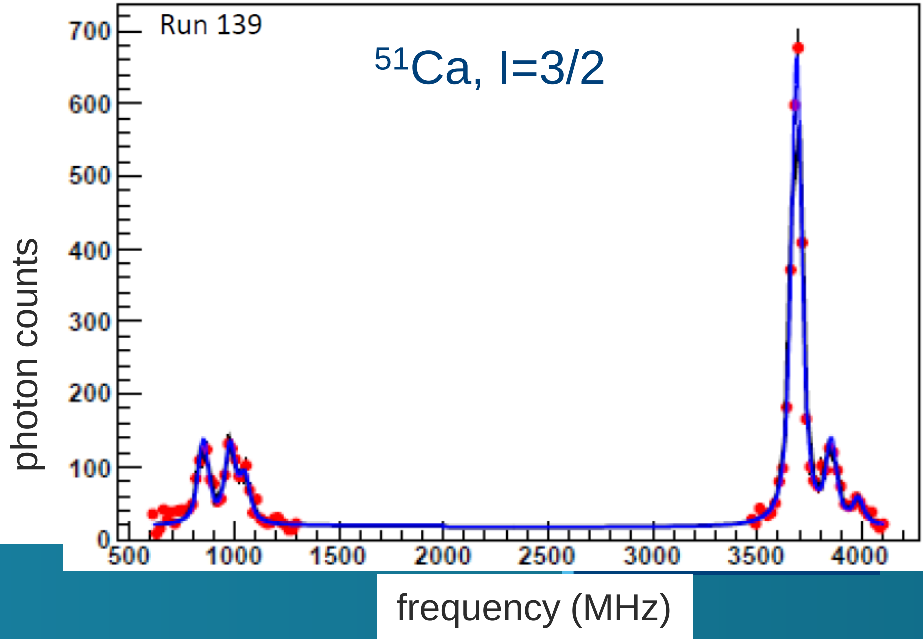
Spin determination of ^{51}Ca: I=3/2

From the constant ratio of hyperfine parameters: $A(S_{1/2}) / A(P_{3/2})$ = const.

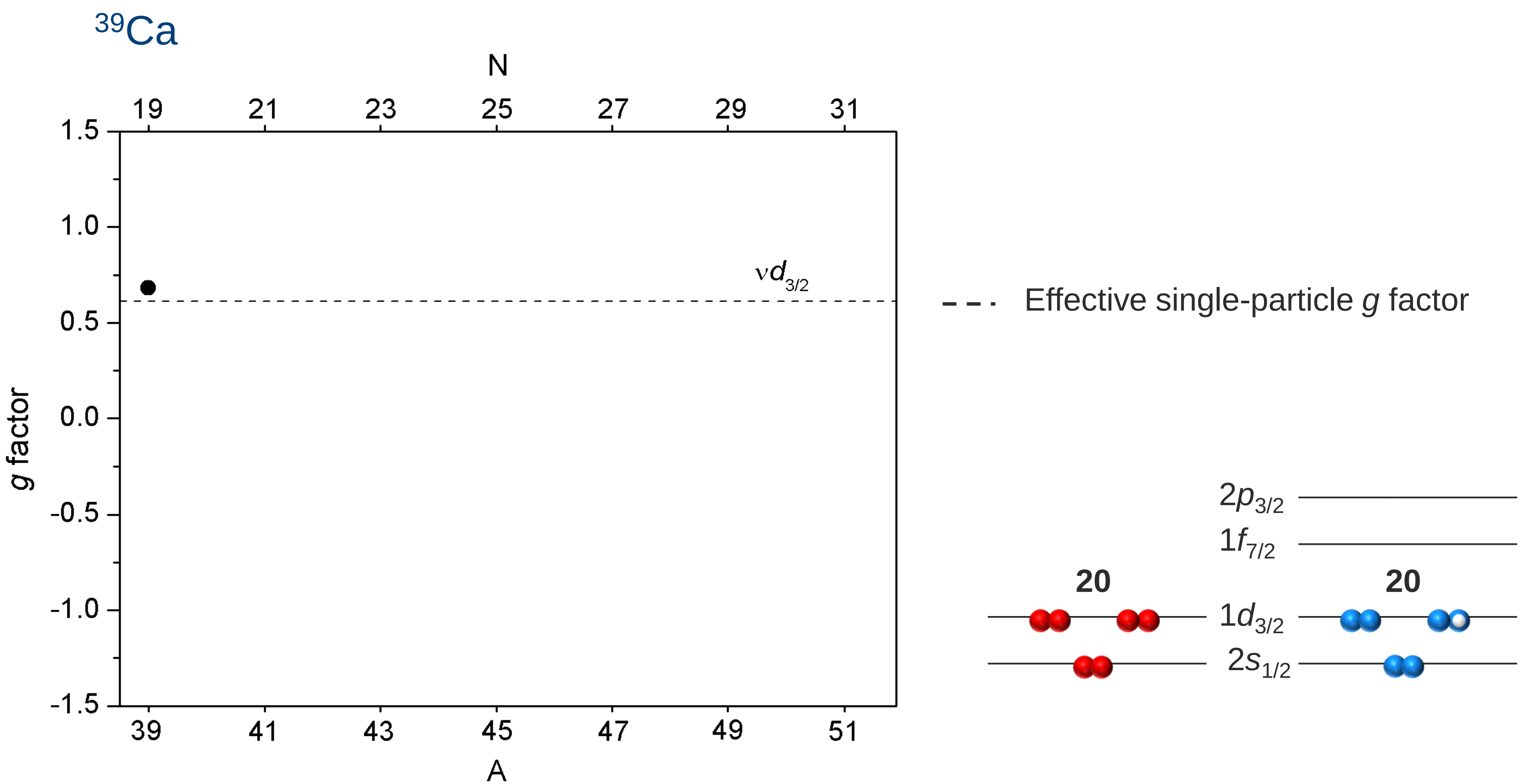


→ only for I=3/2 the ratio fits correctly for ^{49}Ca and ^{51}Ca



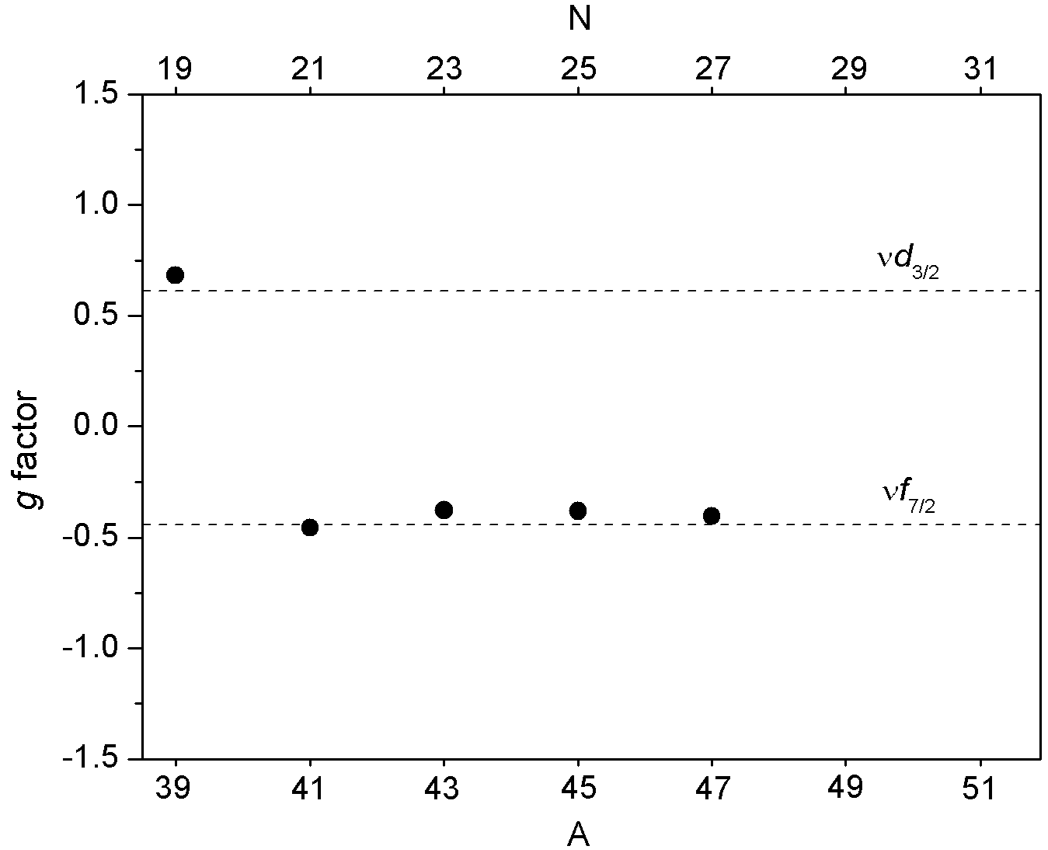


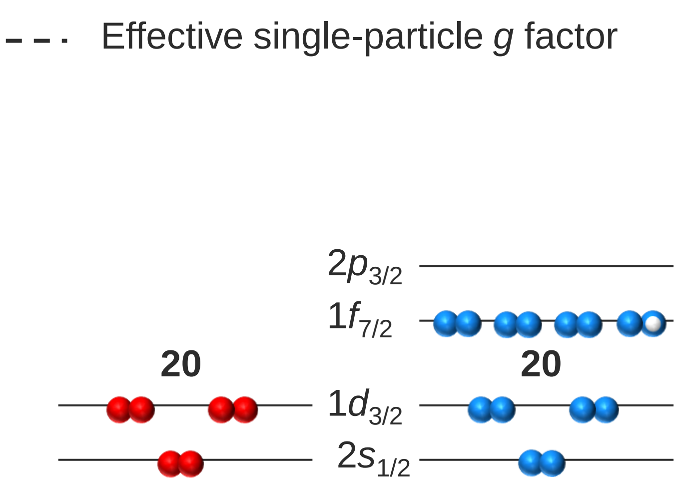
g-factor of odd-A Ca: sensitive to odd neutron



g-factor of odd-A Ca: sensitive to odd neutron

^{41}Ca ------ ^{47}Ca





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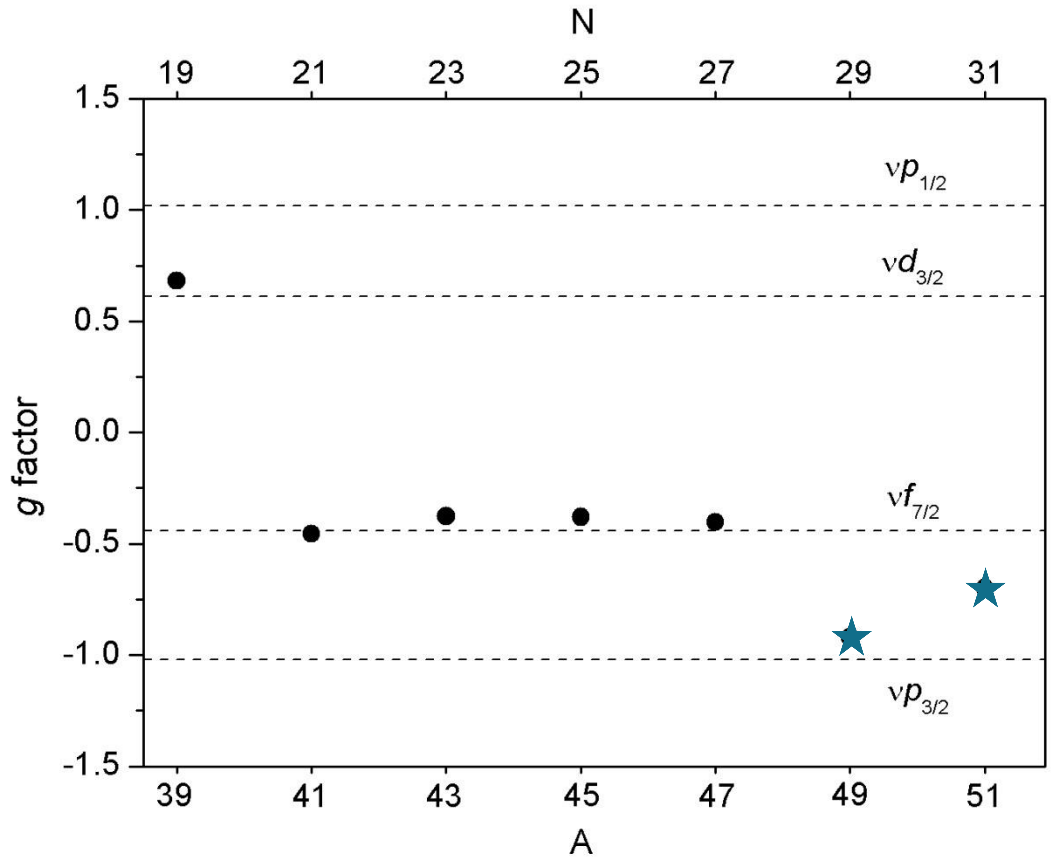
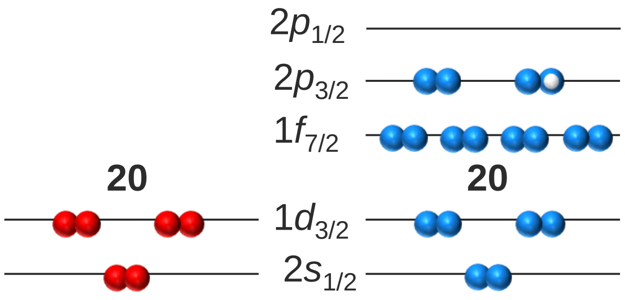
R. F. Garcia Ruiz *et al.*, submitted to PRC

g-factor of odd-A Ca: sensitive to odd neutron

^{49}Ca ^{51}Ca



- - · Effective single-particle *g* factor



^{51}Ca ➔ mixing with configurations from higher ν(*pf*) orbits

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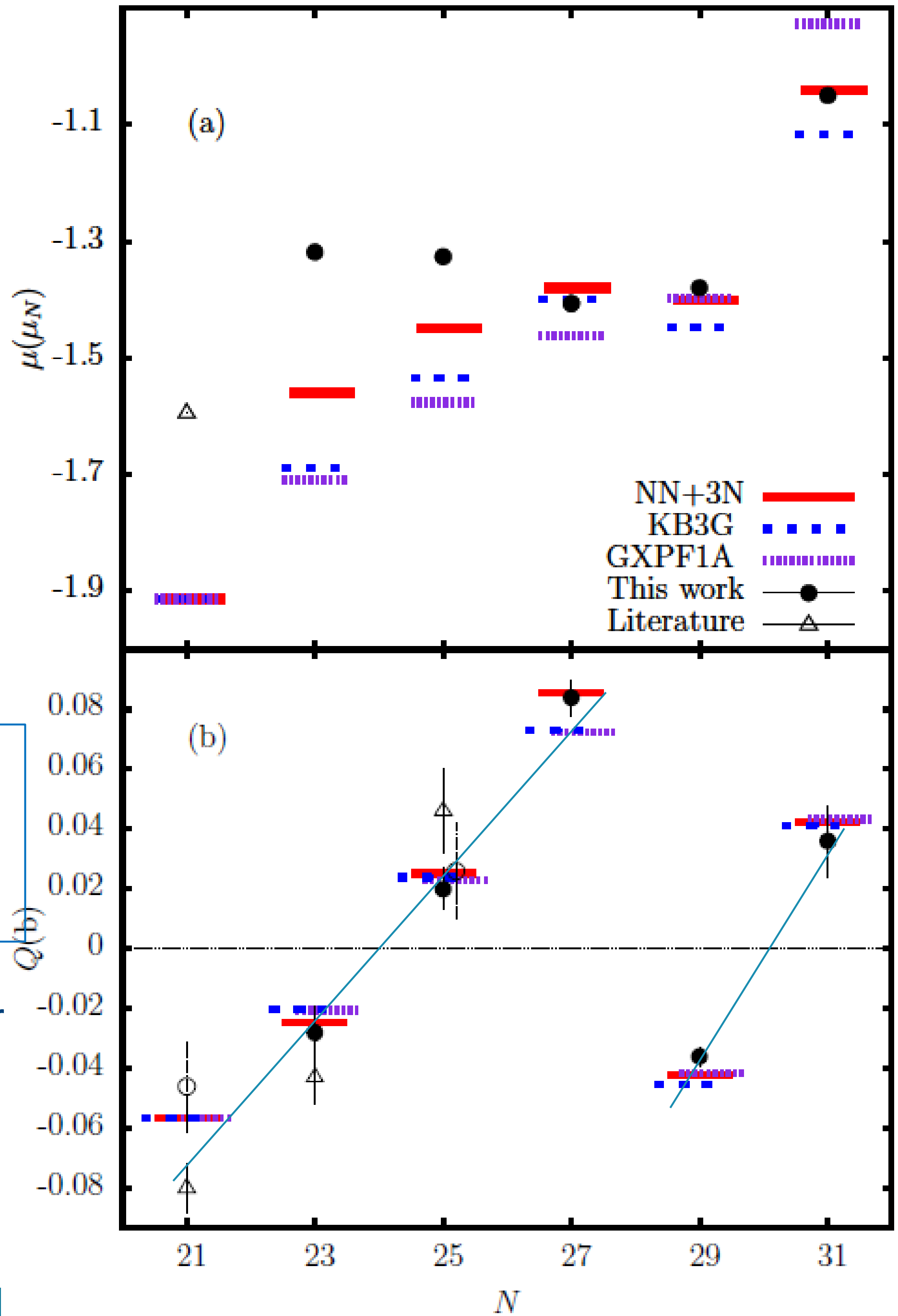
R. F. Garcia Ruiz *et al.*, submitted to PRC

Magnetic moments of odd-Ca:

probing the wave function and testing nuclear theories.

- ➔ All theories fail below N=25
  (need excitations across N,Z=20)
- ➔ good reproduction for ^{47,49,51}Ca
- ➔ larger mixing in 51Ca wave function
  with NN+3N calculations

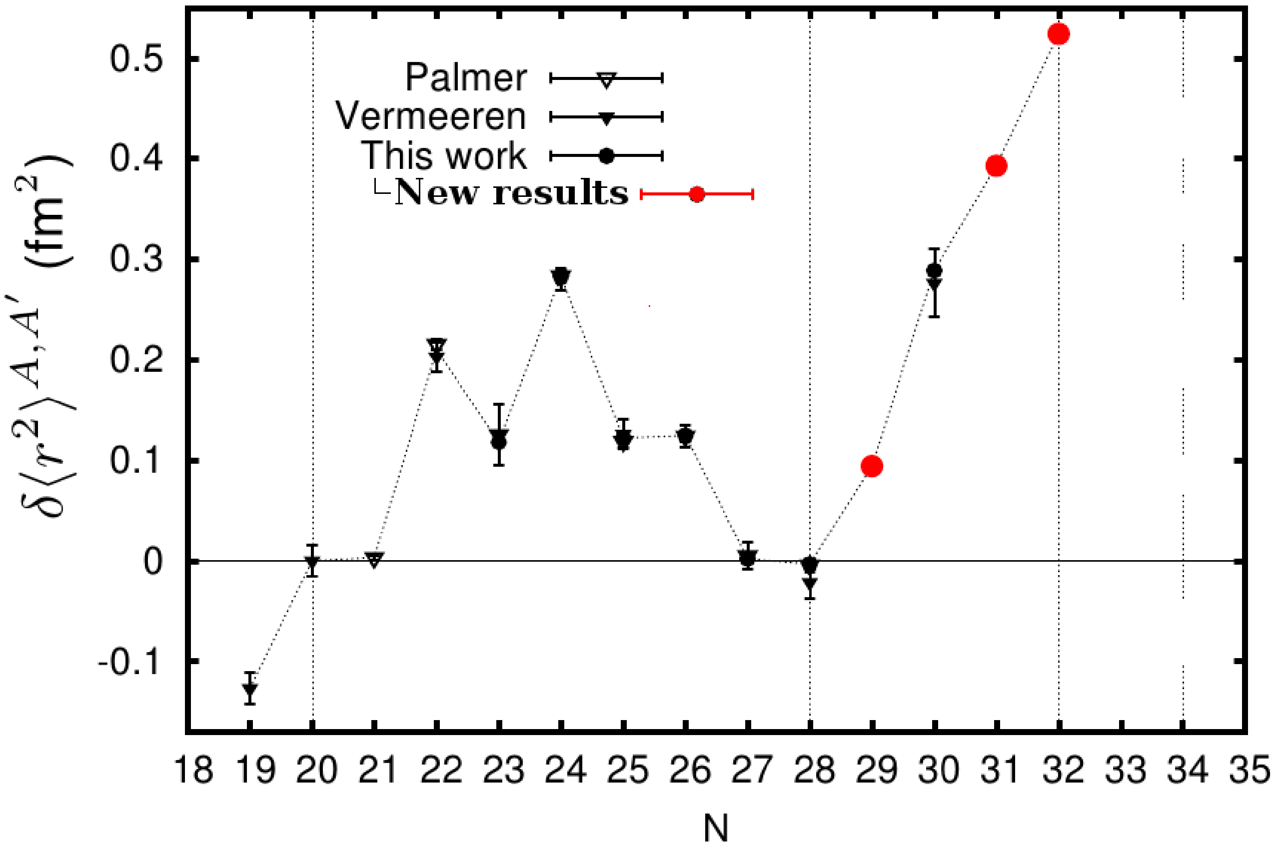


Quadrupole moments of odd-Ca:

follow seniority scheme when filling $f_{7/2}$ and $p_{3/2}$ orbits

- ➔ confirms dominant single particle behavior

Charge radii of Ca isotopes



→ no signature for shell closure at N=32 ?

to be published

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Conclusions and outlook

- K isotopes:
  - magnetic moments, spins and charge radii measured up to N=32
  - no Q-moments (small)

  - re-inversion (back to normal) of proton levels beyond N=30
  - enhanced p-n correlations at N=Z

- Ca isotopes:
  - magnetic moments, spins and radii measured up to N=32
  - Q-moments of all odd-even isotopes up to N=31

  - g-factors reveal less magicity at N=32 than at N=28
  - Q-moments reveal dominant single-particle behavior
  - radii do not show evidence for magic N=32

  ➔ extend measurements to N=34 !

- recent results on Mn isotopes: see **poster 34 by H. Heylen**

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J. Papuga, R. Garcia Ruiz,
H. Heylen, W. Gins, **M. Bissell,**
G. Neyens

K. Kreim, K. Blaum, R. Neugart

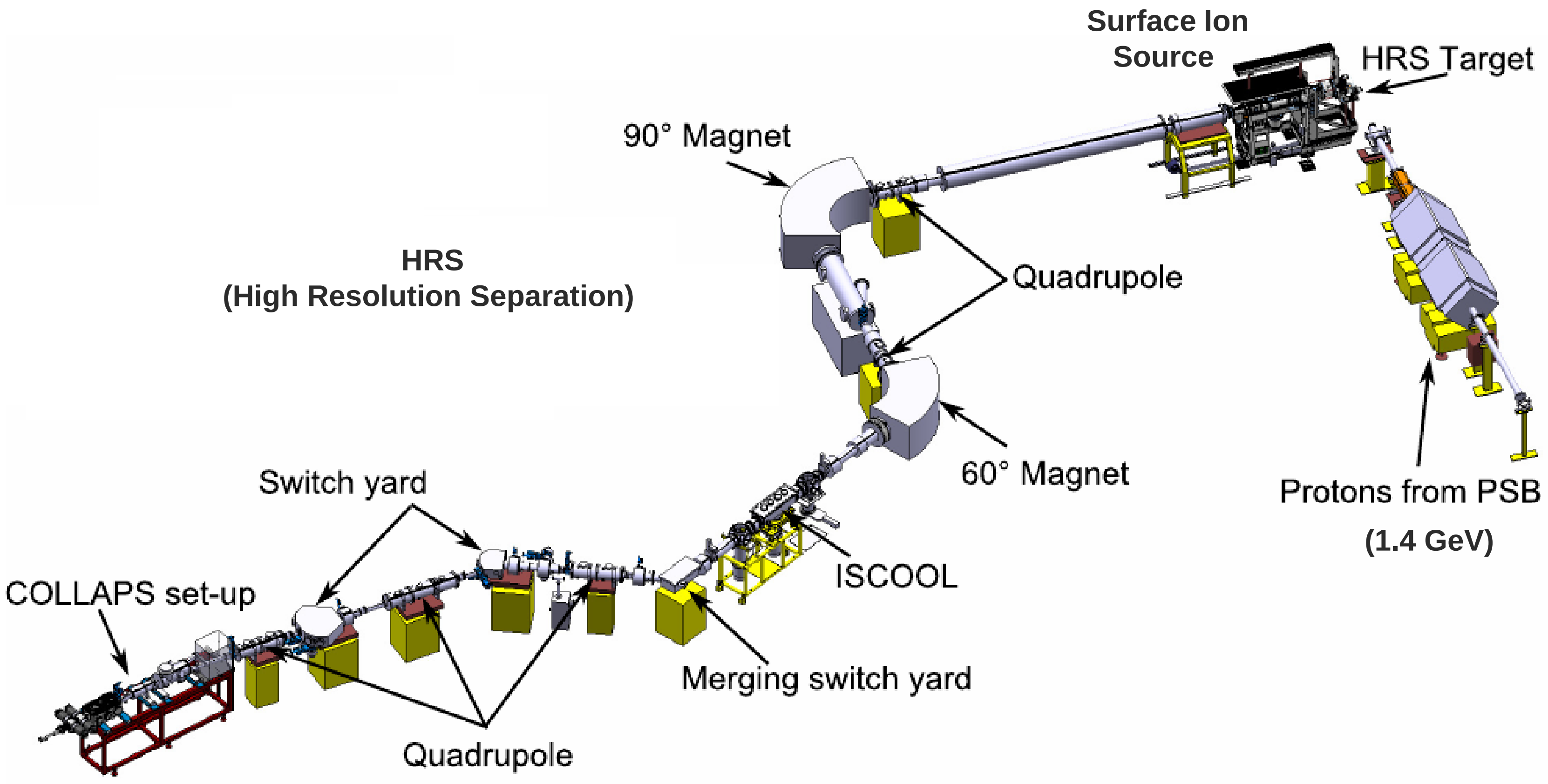
R. Sanchez, C. Geppert,
L. Grob, N. Frommen,
W. Nörtershäuser

D. Yordanov, M. Kowalska

Thank you for your attention!

Setup – Ion beam

ISOLDE (Isotope Separator On-Line DEvice)



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