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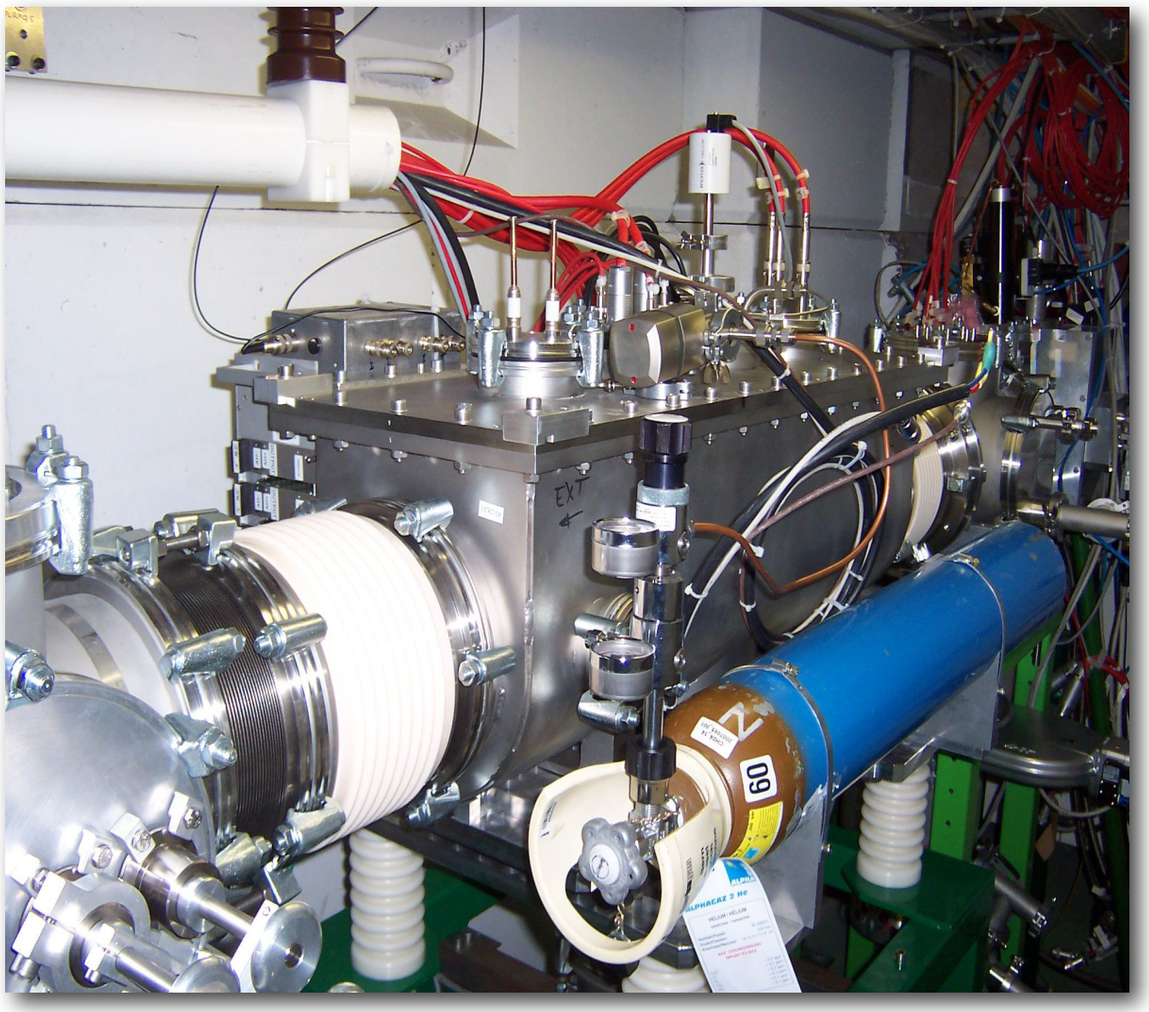
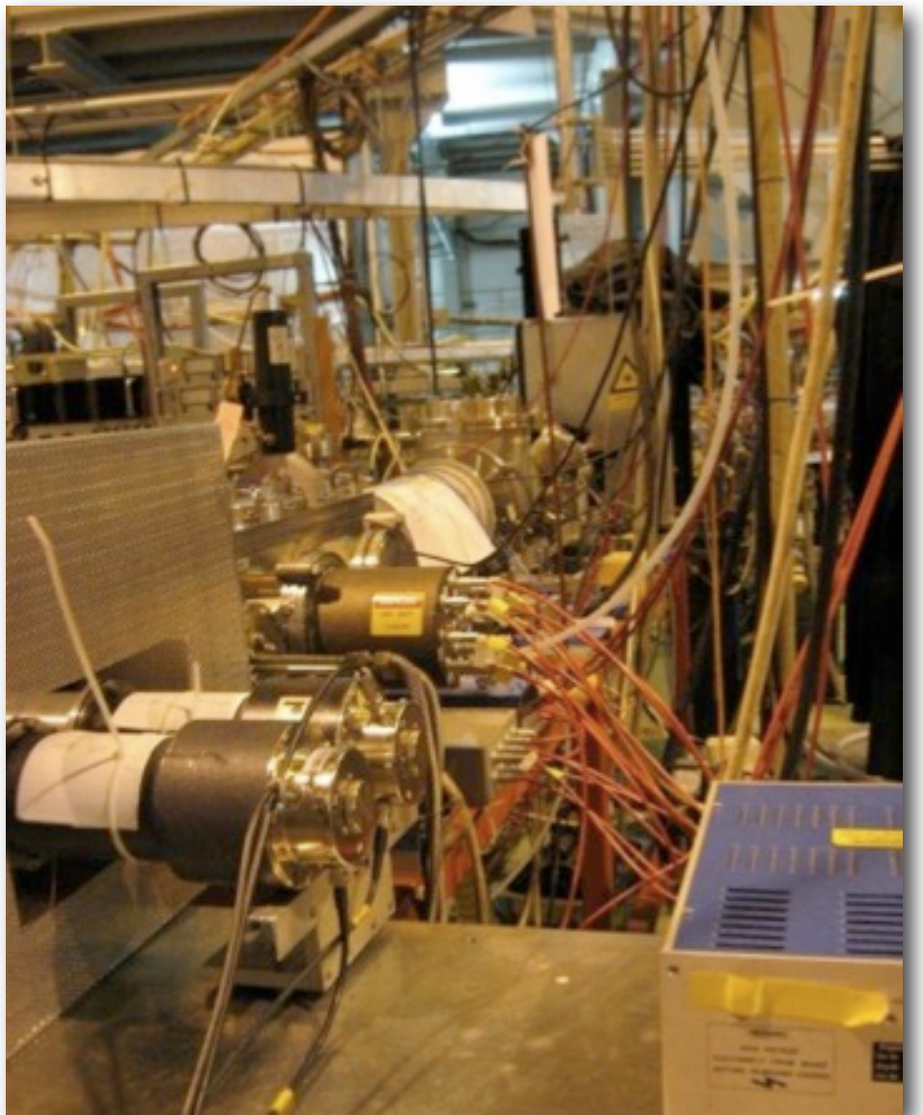
Laser spectroscopy of gallium isotopes using ISCOOL





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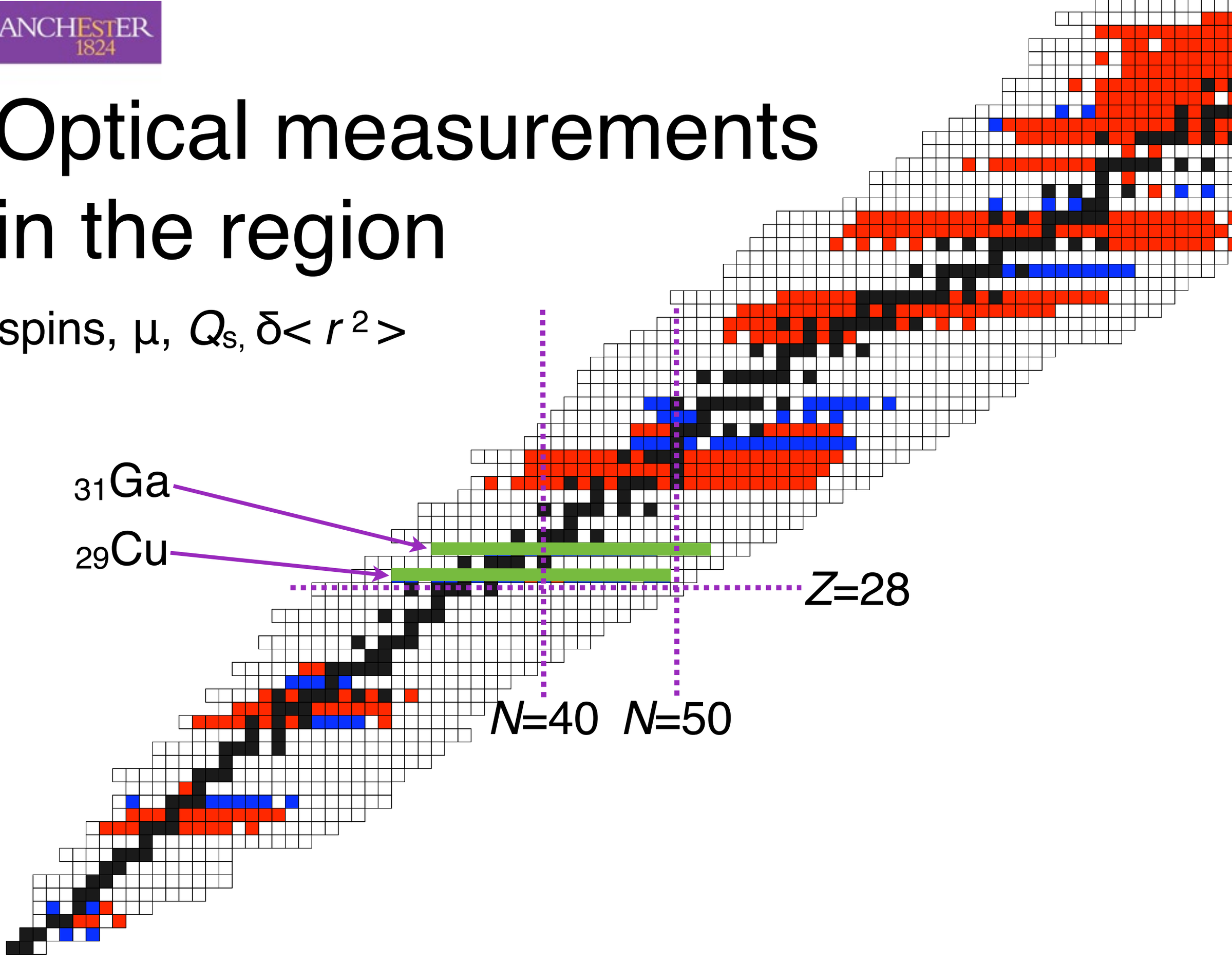
Optical measurements in the region

→ spins, μ, Q_s, δ< r^2 >



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Physics motivation

Otsuka (PRL 95 232502):-

Tensor force **attractive** between L+1/2 and L-1/2

(esp with ~radial wavef^{n})

Does 5/2 replace 3/2 as gs in Ga? When?

Use laser spectroscopy to measure the gs spins...

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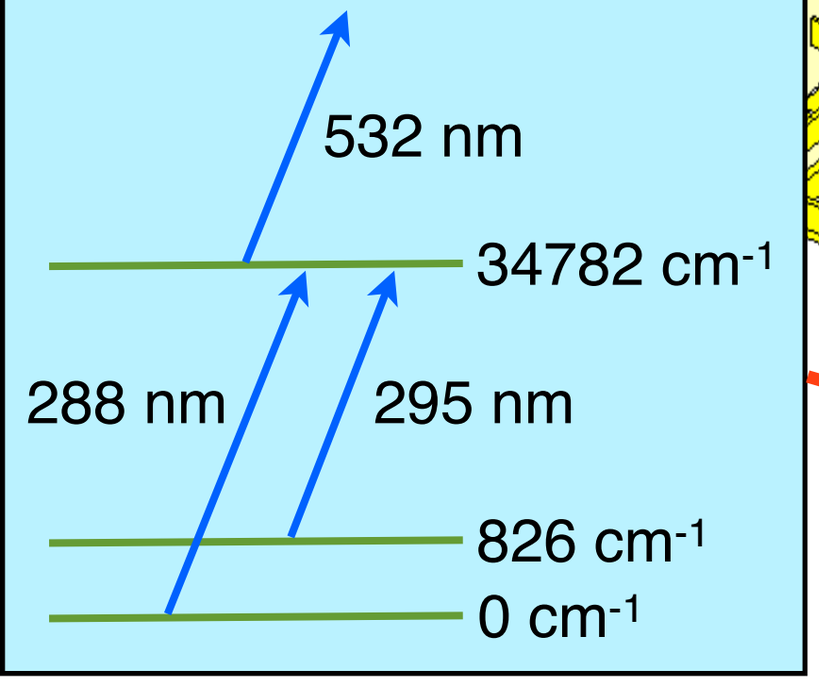
Laser spectroscopy at Collaps

RILIS

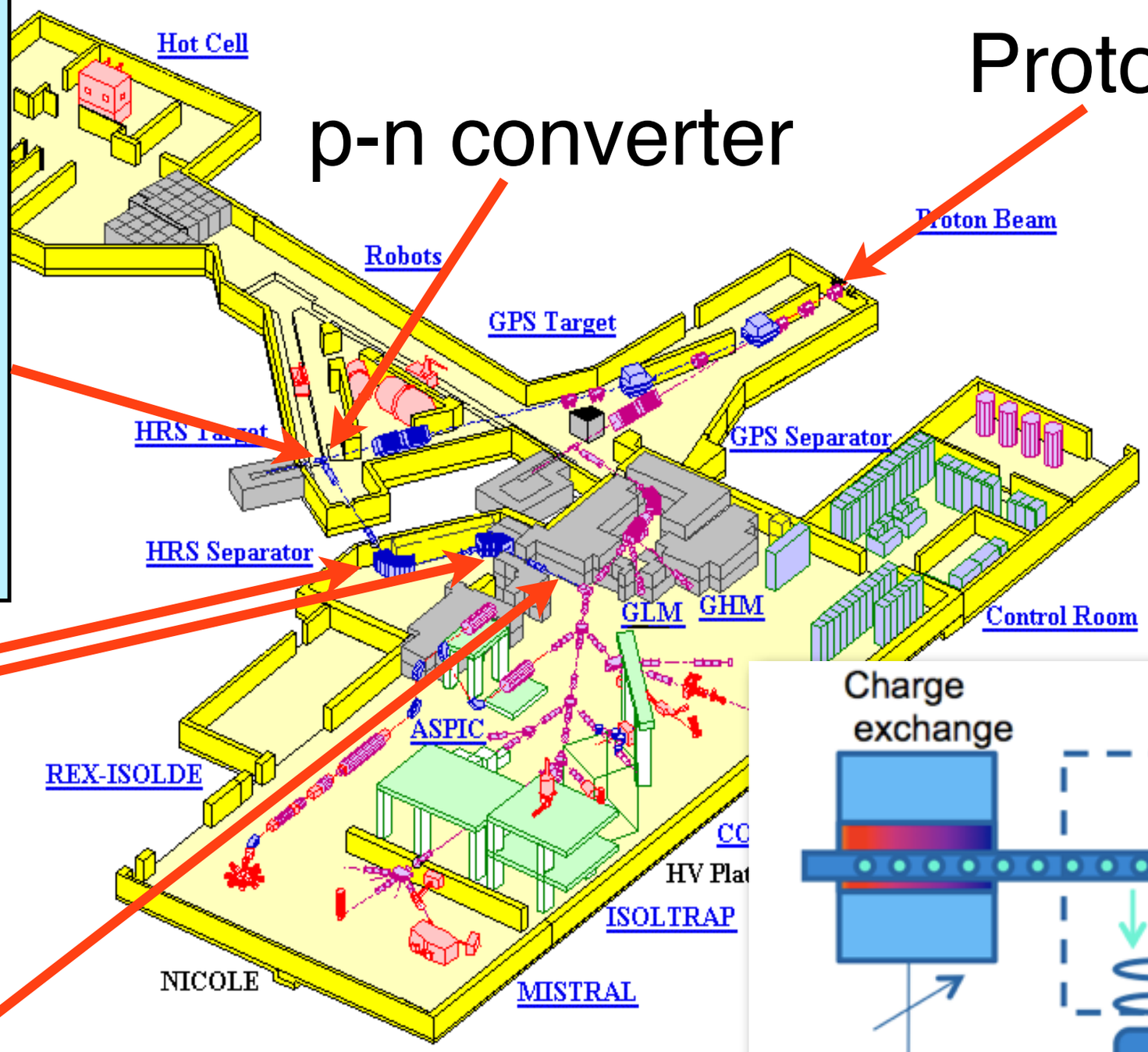


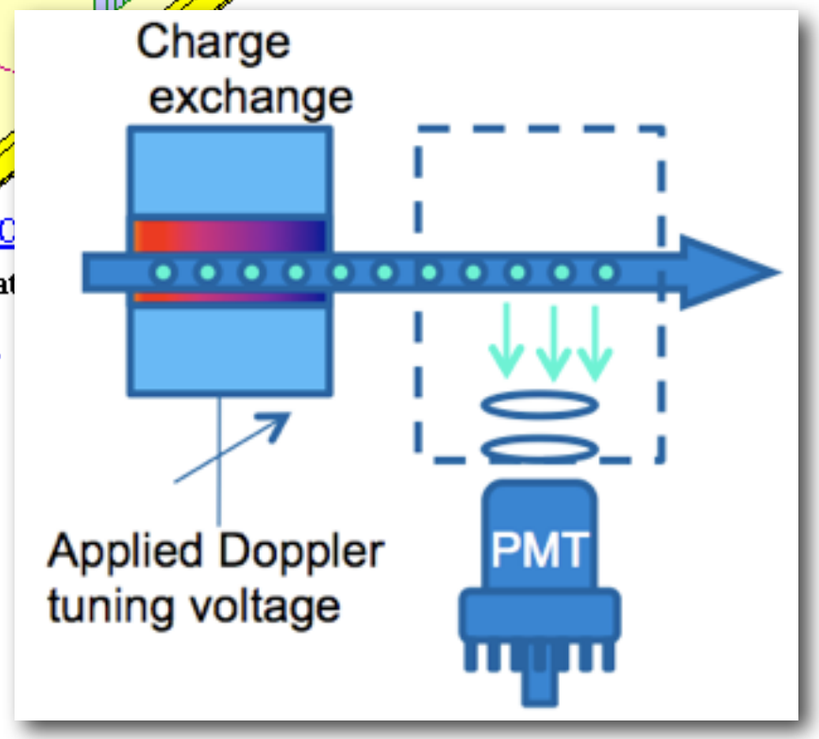
Protons

p-n converter

Magnets

ISCOOL





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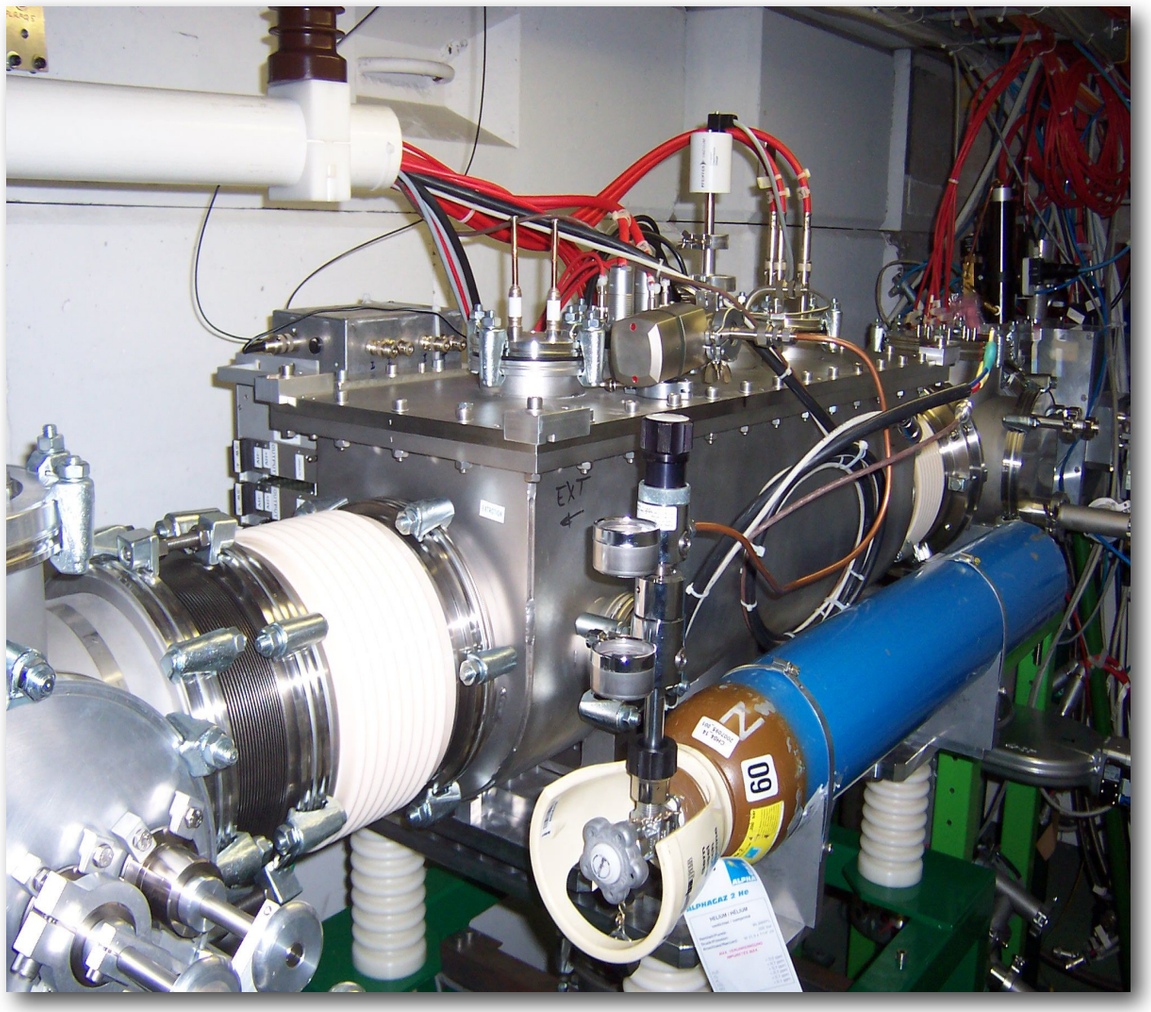
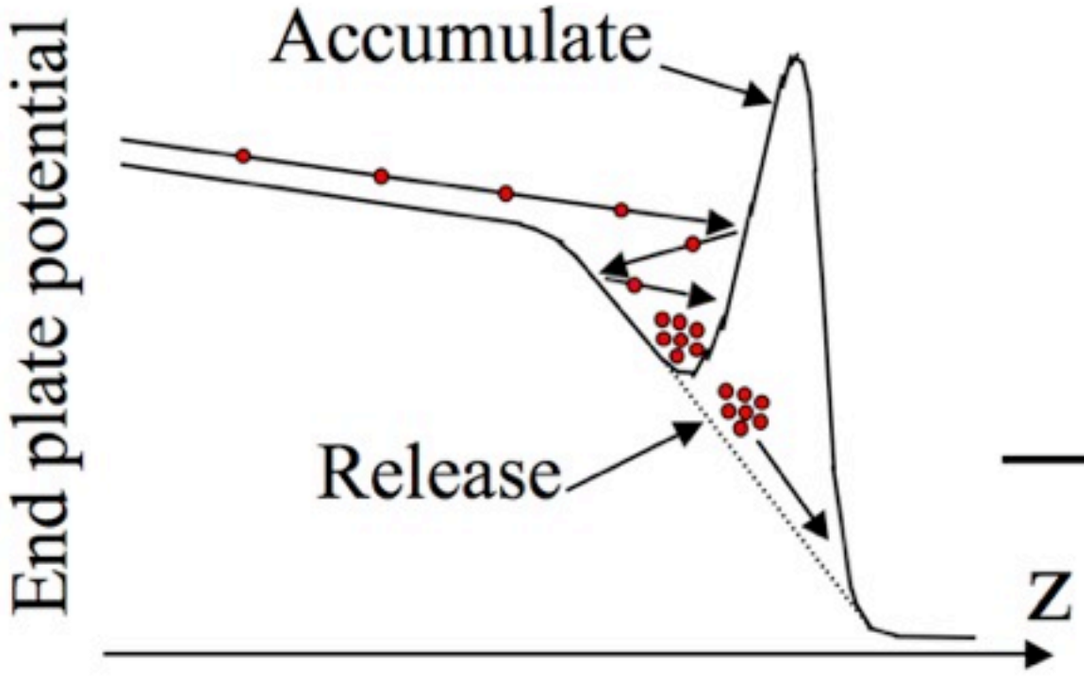
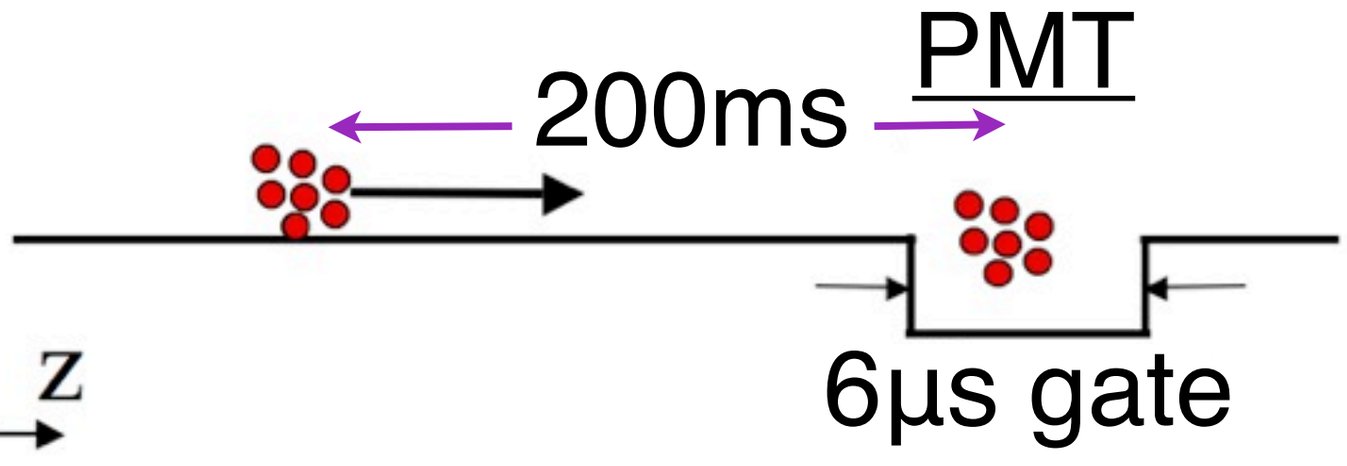
ISCOOL for cooling & bunching

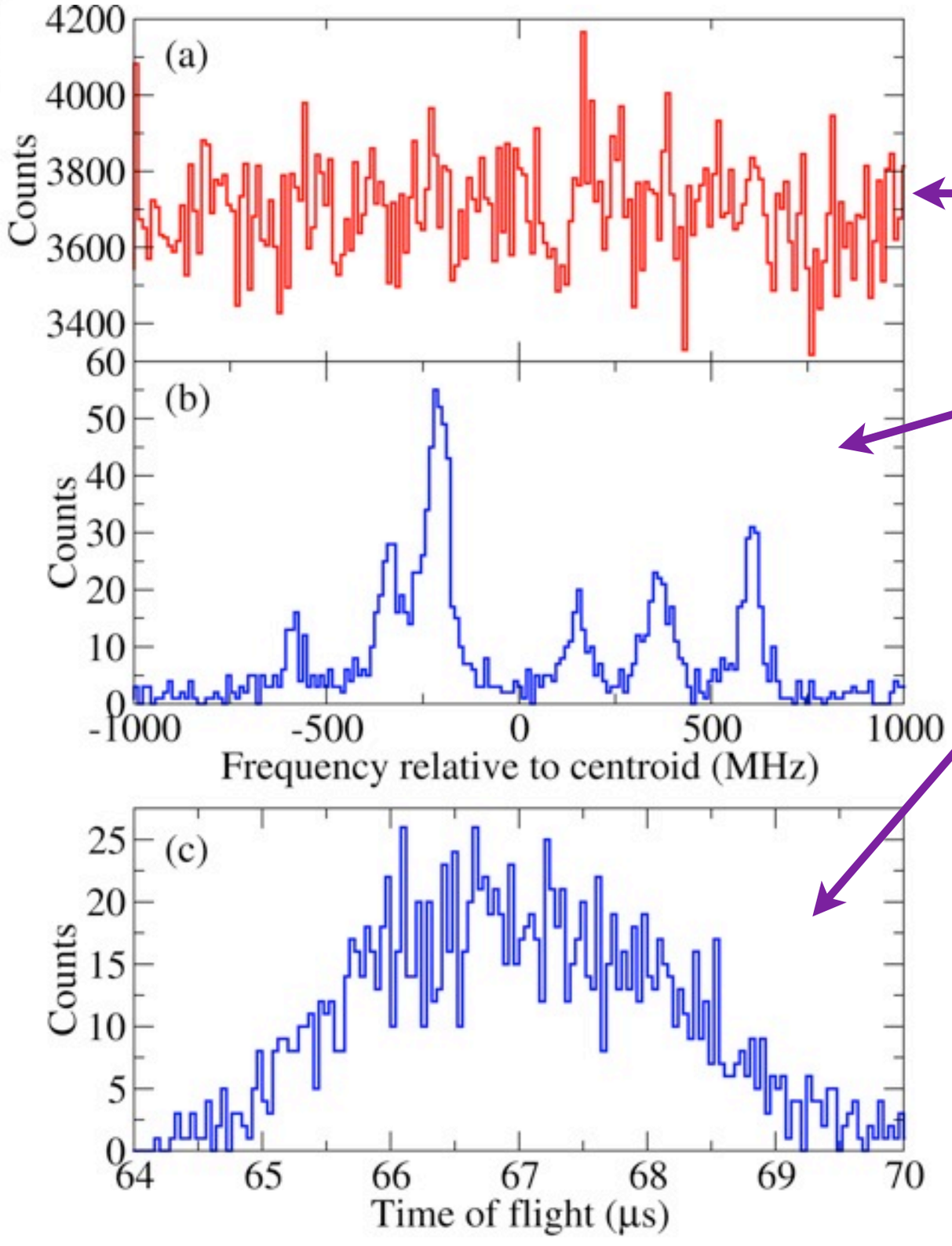
Photon background dominated by continuous laser scatter







Example spectrum - ^{76}Ga



Ungated

Gated (64μs - 70μs)

Time of flight
(50ms accumulation)

<u>Background suppression</u>

50ms / 6μs = ~10^4

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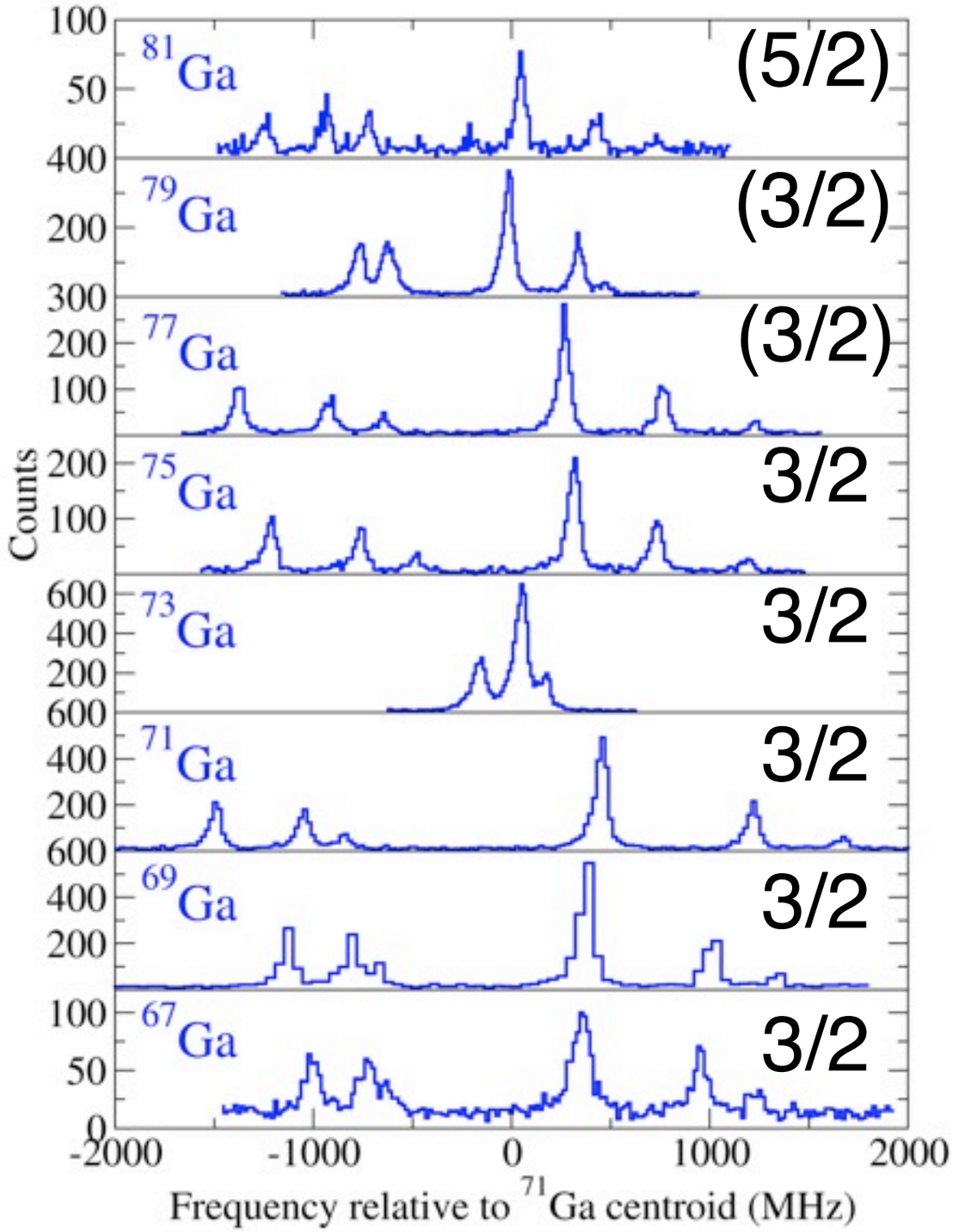
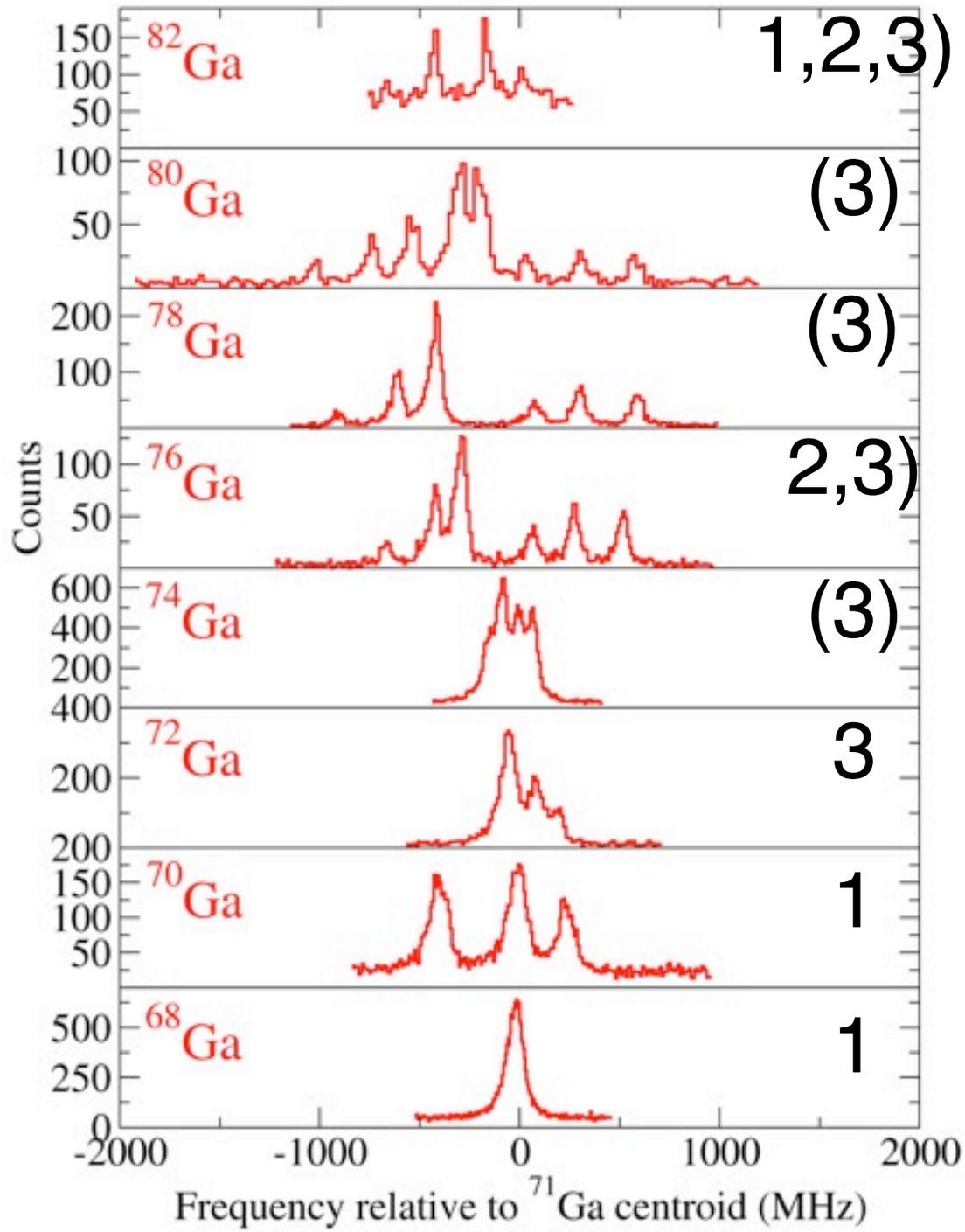
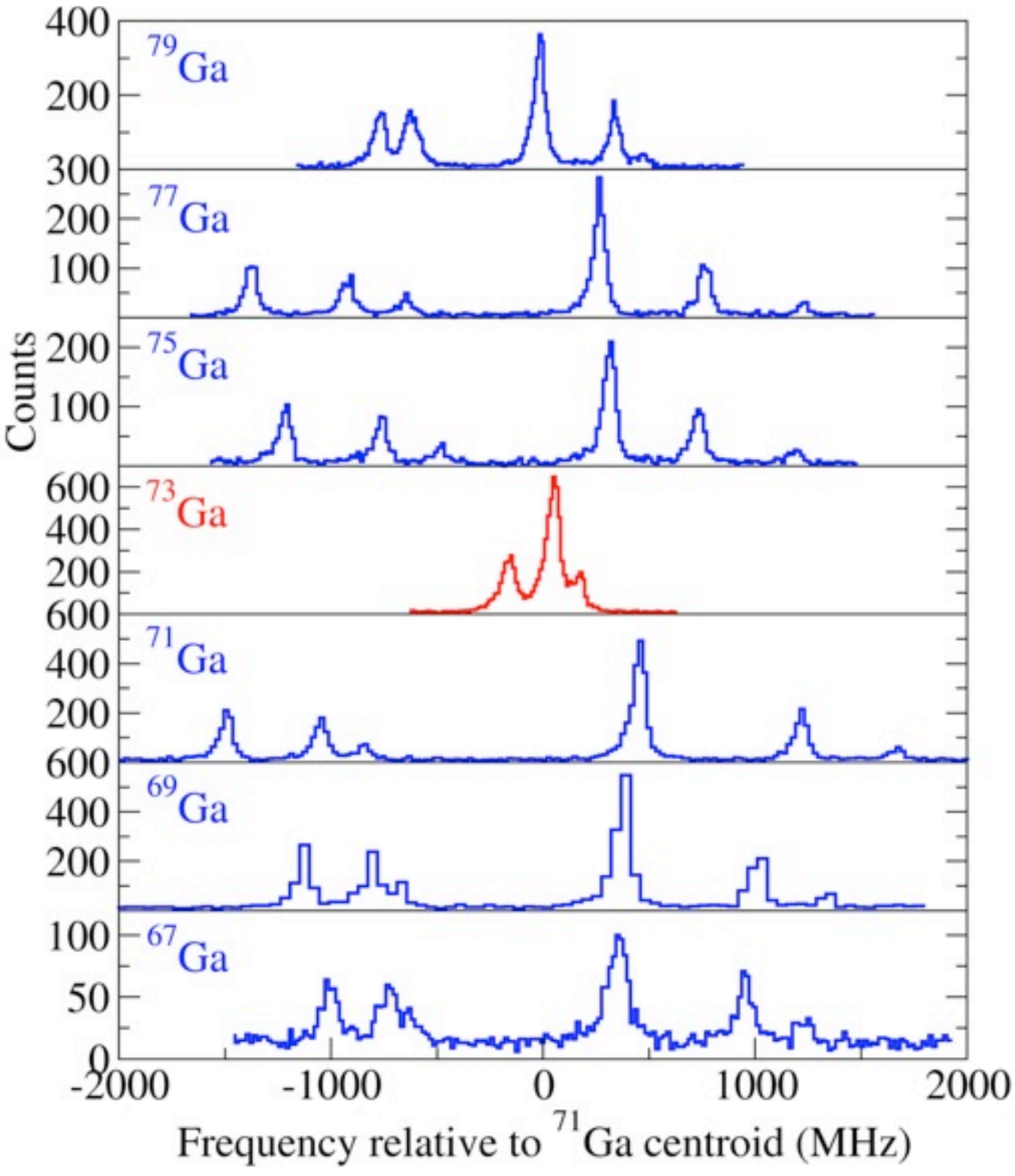
417nm Ga I spectra

826 cm^{-1} $3d^{10}4s^24p\ ^2P_{3/2}$ → 24789 cm^{-1} $4s^25s\ ^2S_{1/2}$





The strange case of ^{73}Ga

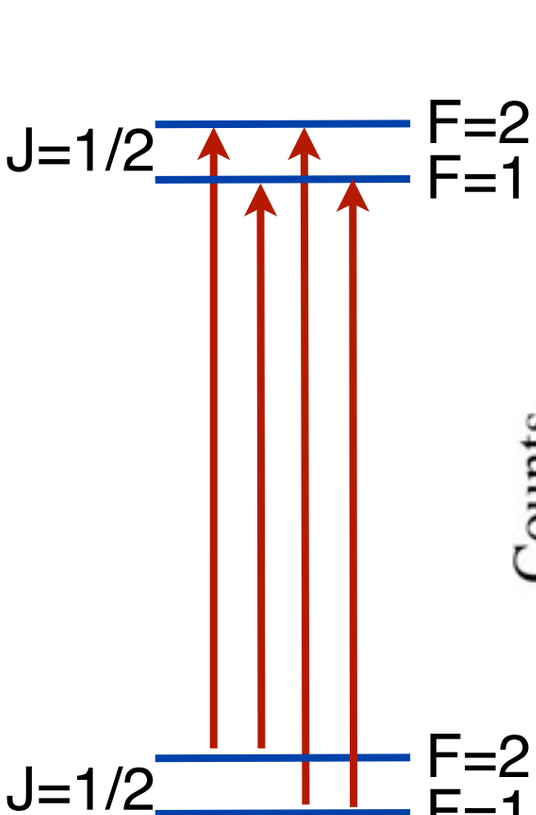


All odd-*A* states previously assigned *I*=3/2

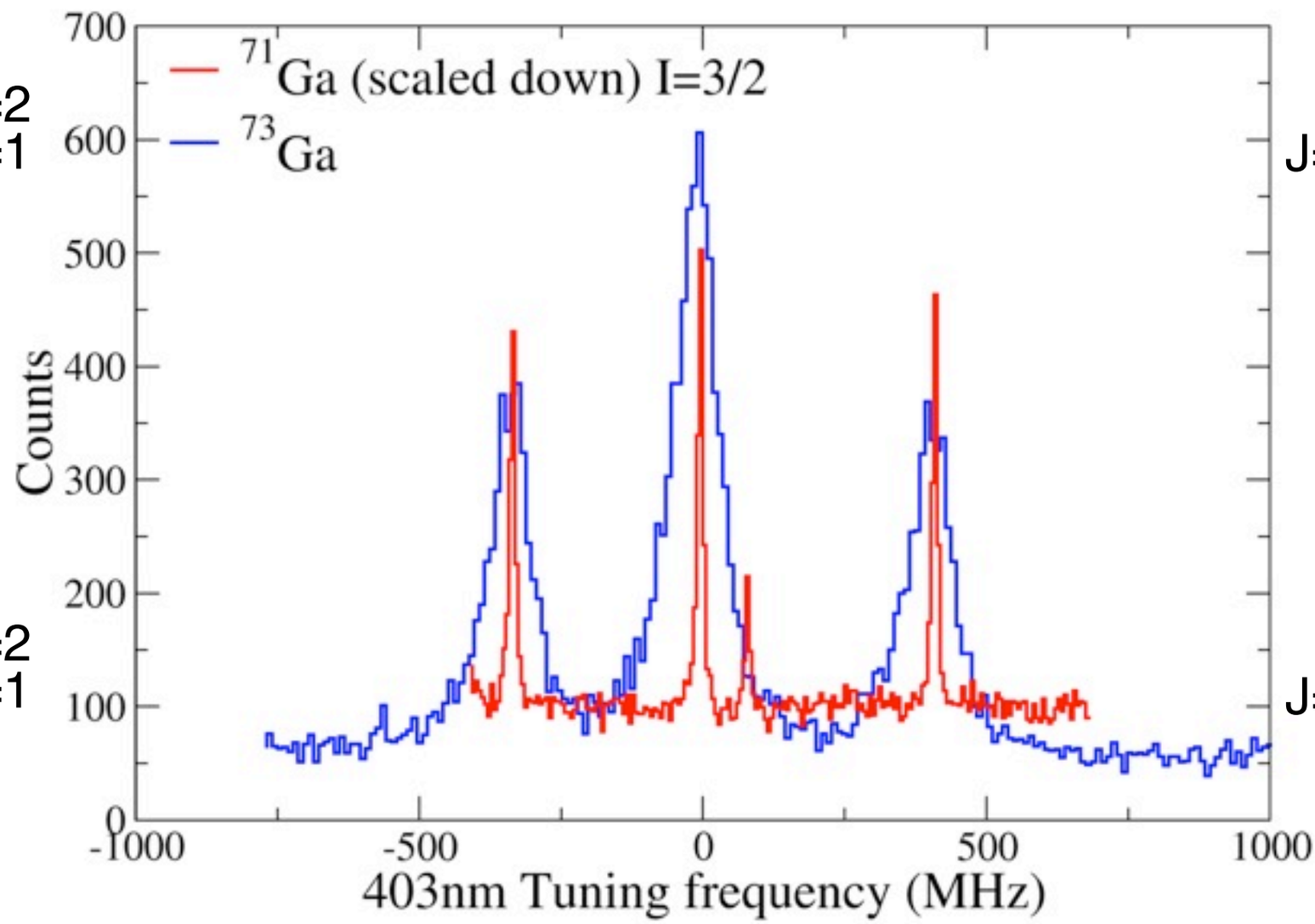
$\pi(p_{3/2})^3$ - hole state

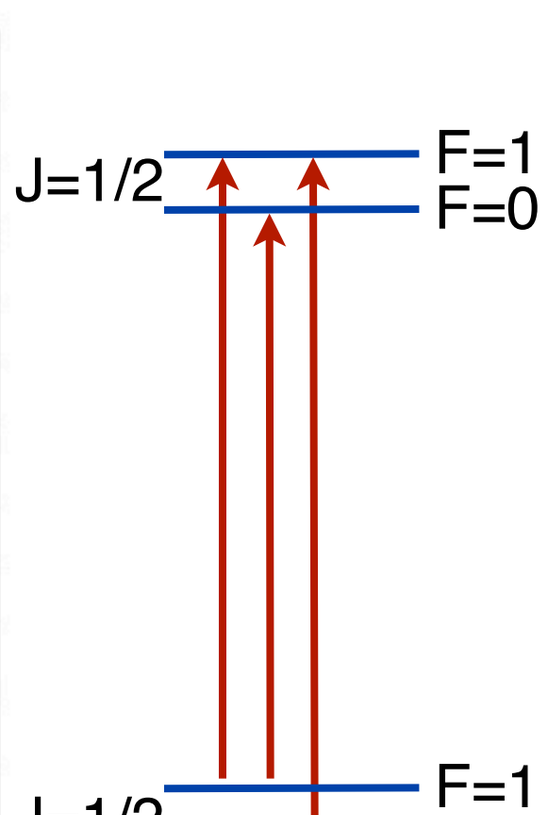
Au/Al ≠ 5.59(2)

403nm ($^2P_{1/2}$ ➔ $^2S_{1/2}$) transition



I=3/2

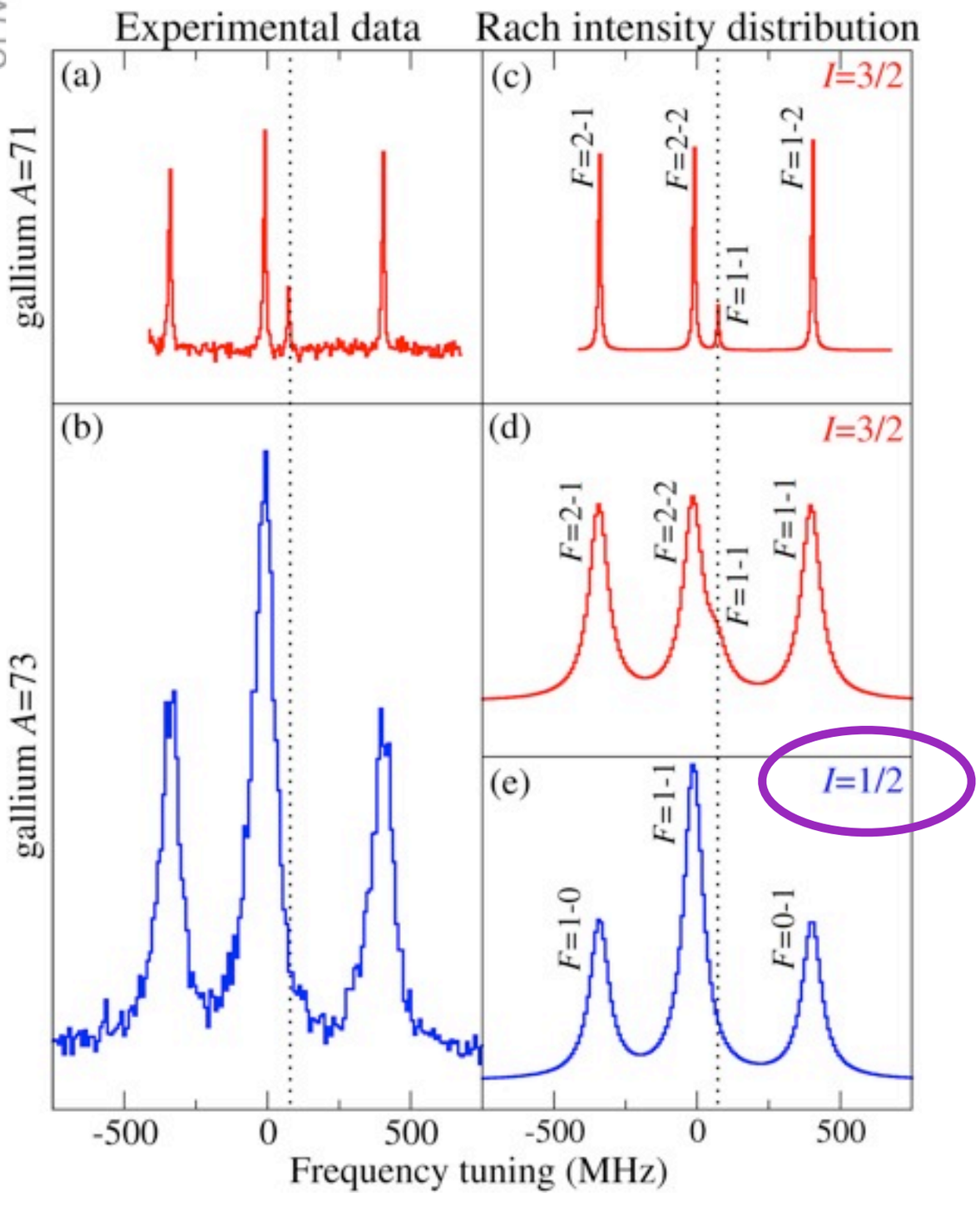




I=1/2

➔ Must be spin 1/2

Intensity distribution (403nm)



✔ Number of peaks

✔ Intensity distribution

✔ Au($^2S_{1/2}$):Al($^2P_{3/2}$) ratio

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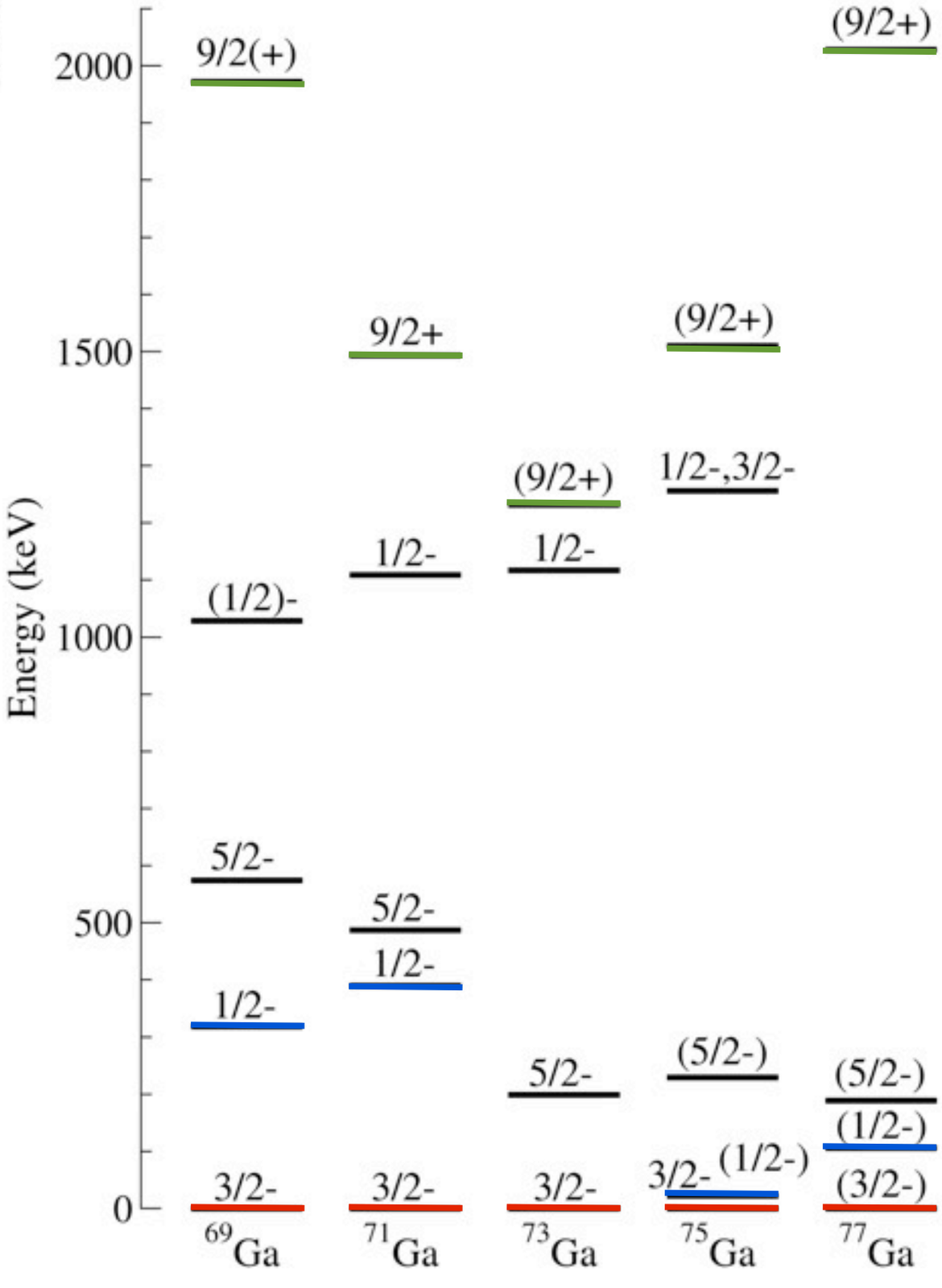
Gallium level systematics



No low-lying spin-1/2 state observed in ^{73}Ga

Dip in 9/2 energy at this point (onset of deformation)

I. Stefanescu *et al.* PRC 79, 064302 (2009)

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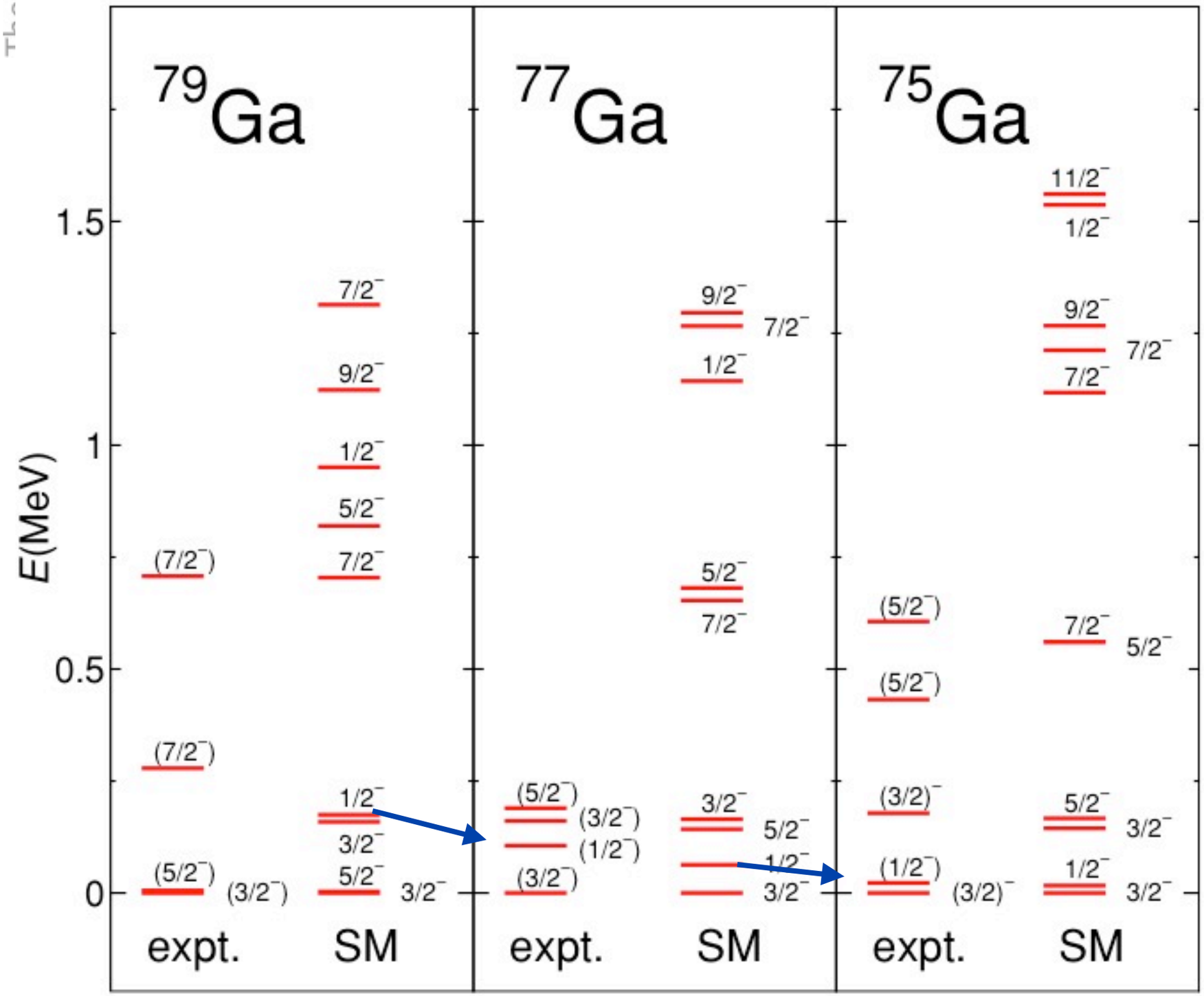
Shell model predictions



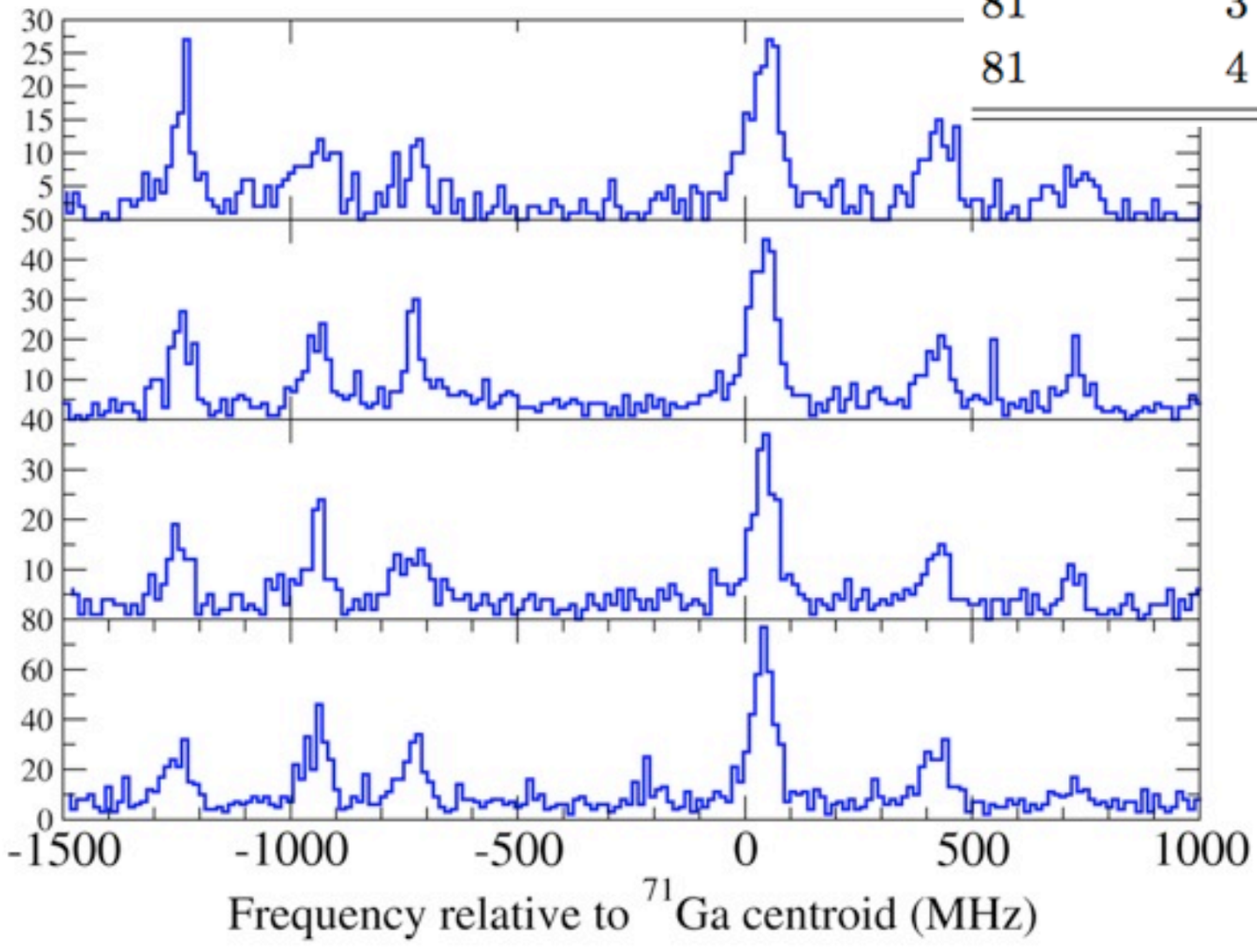
Pairing + QQ using a valence space made up from nucleons occupying the $g_{9/2}$, $p_{1/2}$, $p_{3/2}$ and $f_{5/2}$ orbitals

N. Yoshinaga, K. Higashiyama, and P. H. Regan PRC **78** 044320 (2008)

Searching for the I=5/2...

Four ^{81}Ga spectra:-

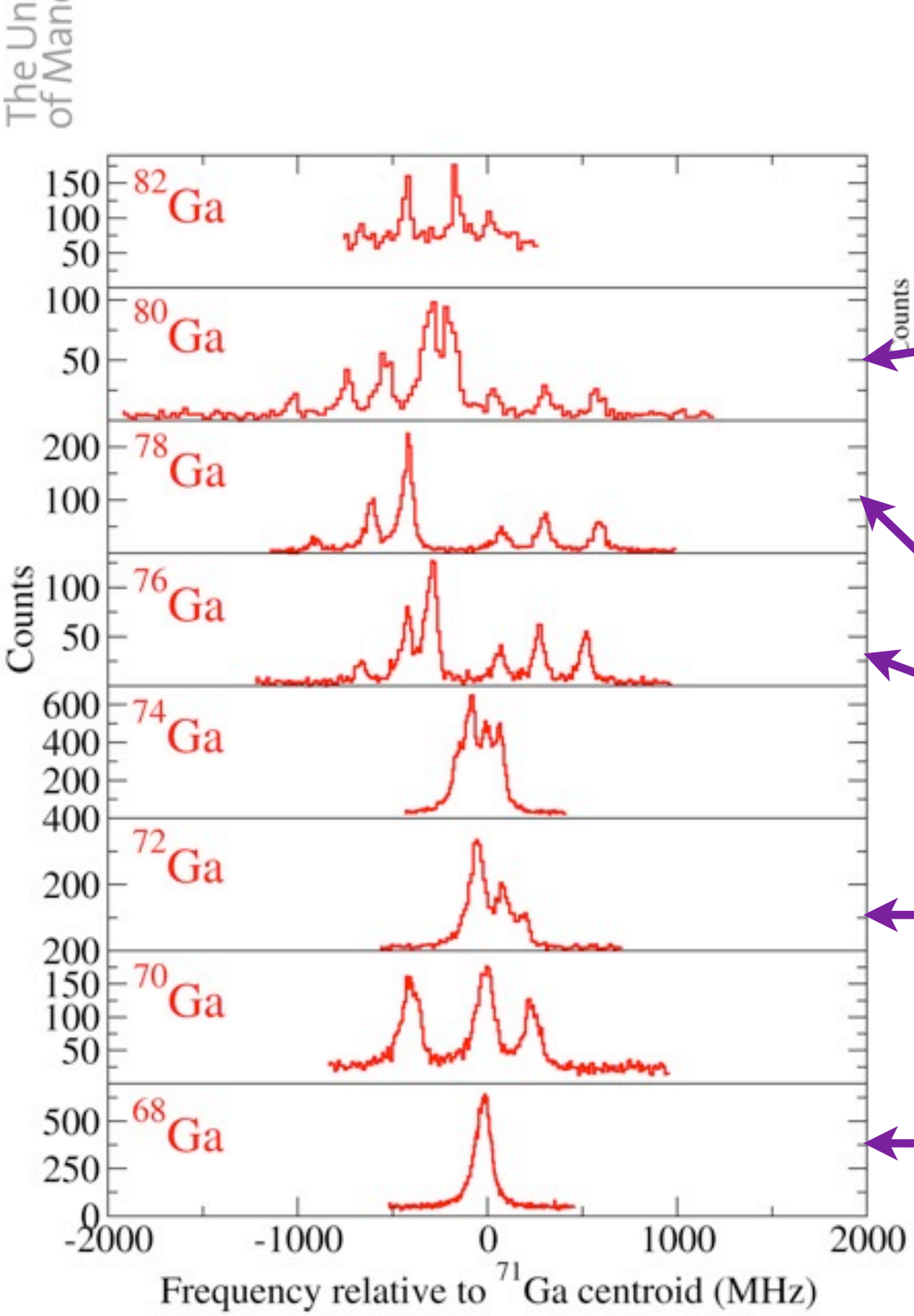
		$I = 3/2$		$I = 5/2$	
A	Data Set	χ^2	χ^2_r	χ^2	χ^2_r
79	1	299	1.54	563	2.90
79	2	259	1.33	398	2.05
81	1	274	1.40	205	1.05
81	2	369	1.89	234	1.20
81	3	288	1.48	176	0.90
81	4	402	2.06	256	1.31

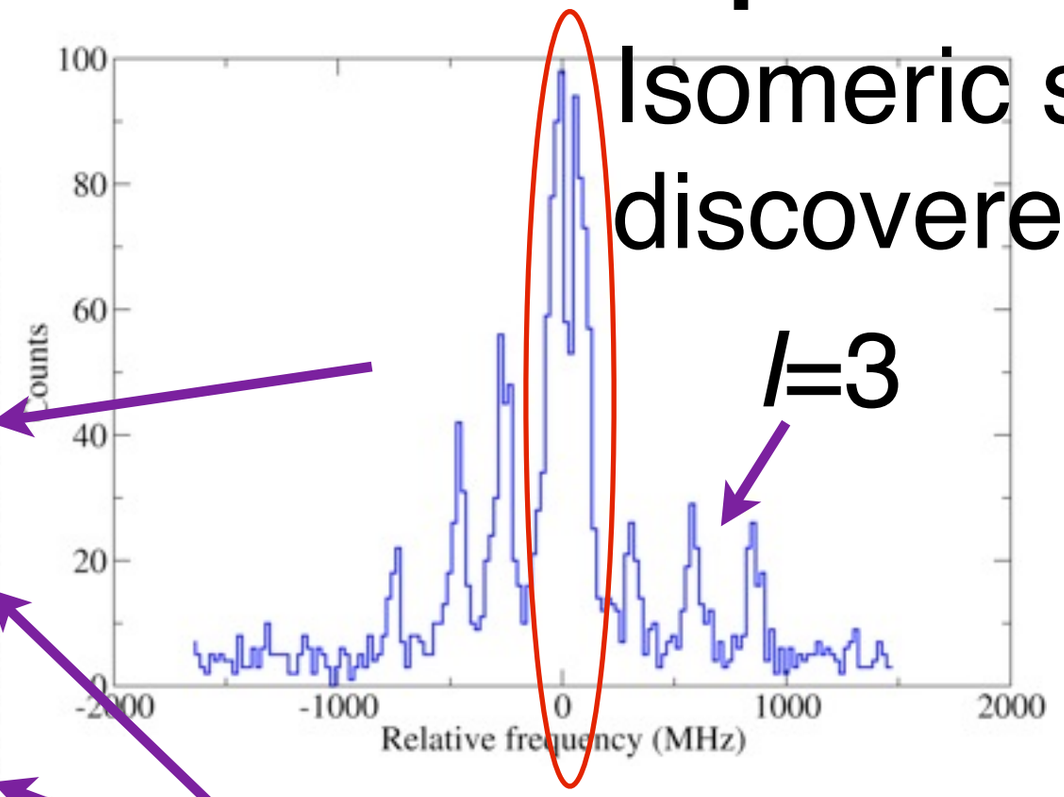


^{75,77,79}Ga are I = 3/2

^{81}Ga is I = 5/2

Odd-odd Ga isotopes





Isomeric state discovered in ^{80}Ga

I=3

Can assign as I=2

Agrees with ABMR

No detectable splitting

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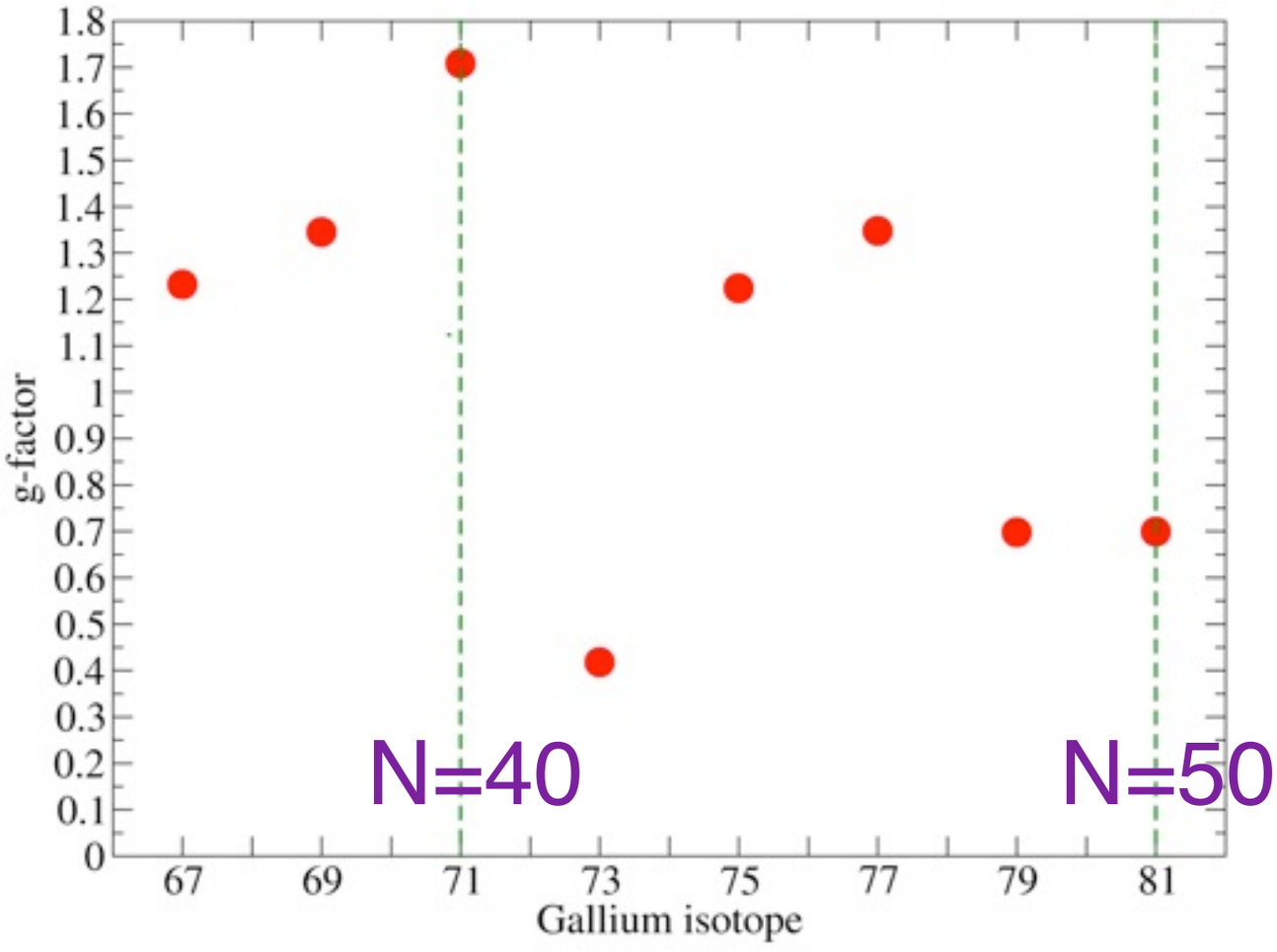
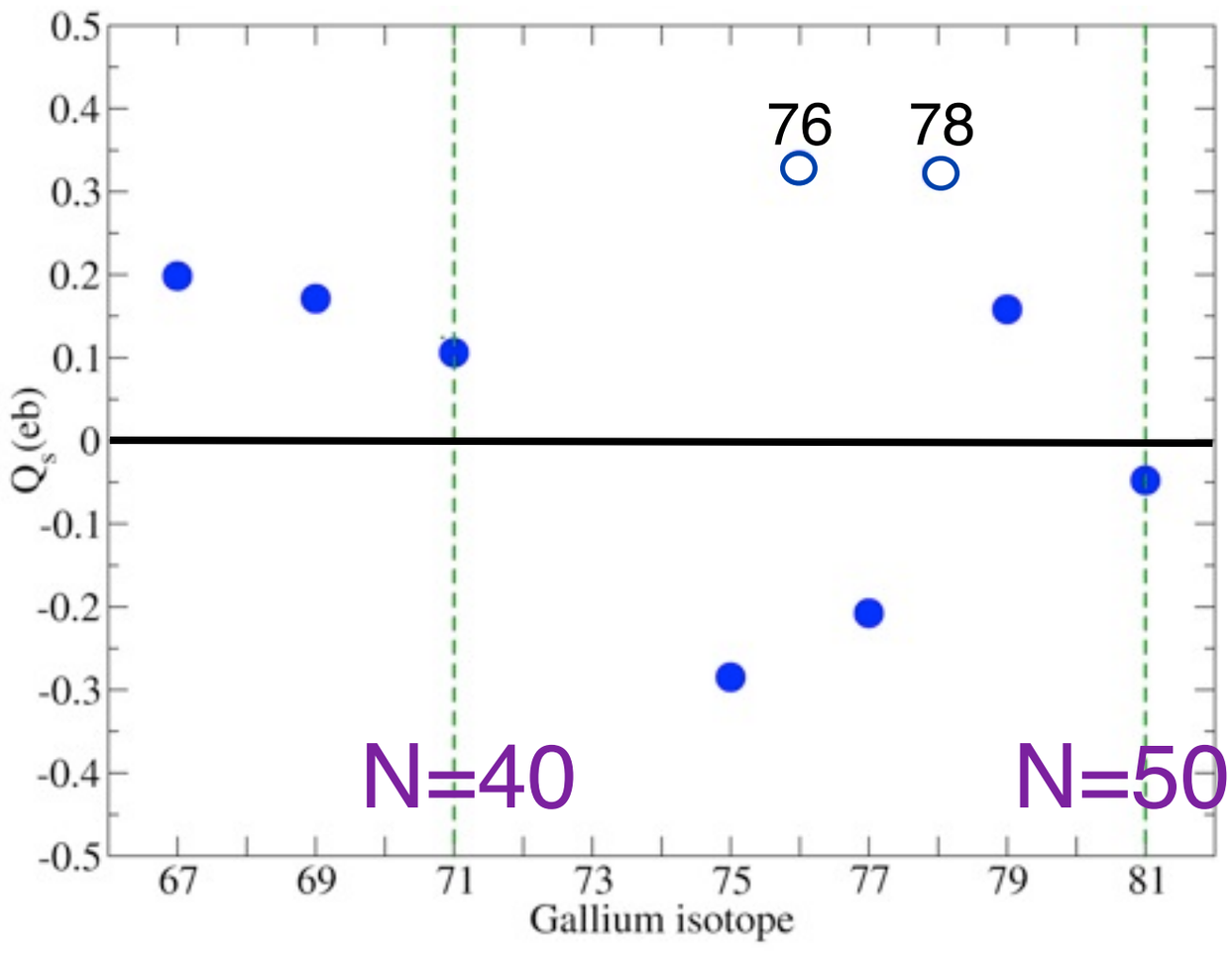
Gallium nuclear moments

g-factors



Q_s



- g-factors of ^{75,77}Ga similar to ^{67,69,71}Ga
  → but different structure ($Q < 0$)
- Staggering of quadrupole moments ^{75,76,77,78}Ga

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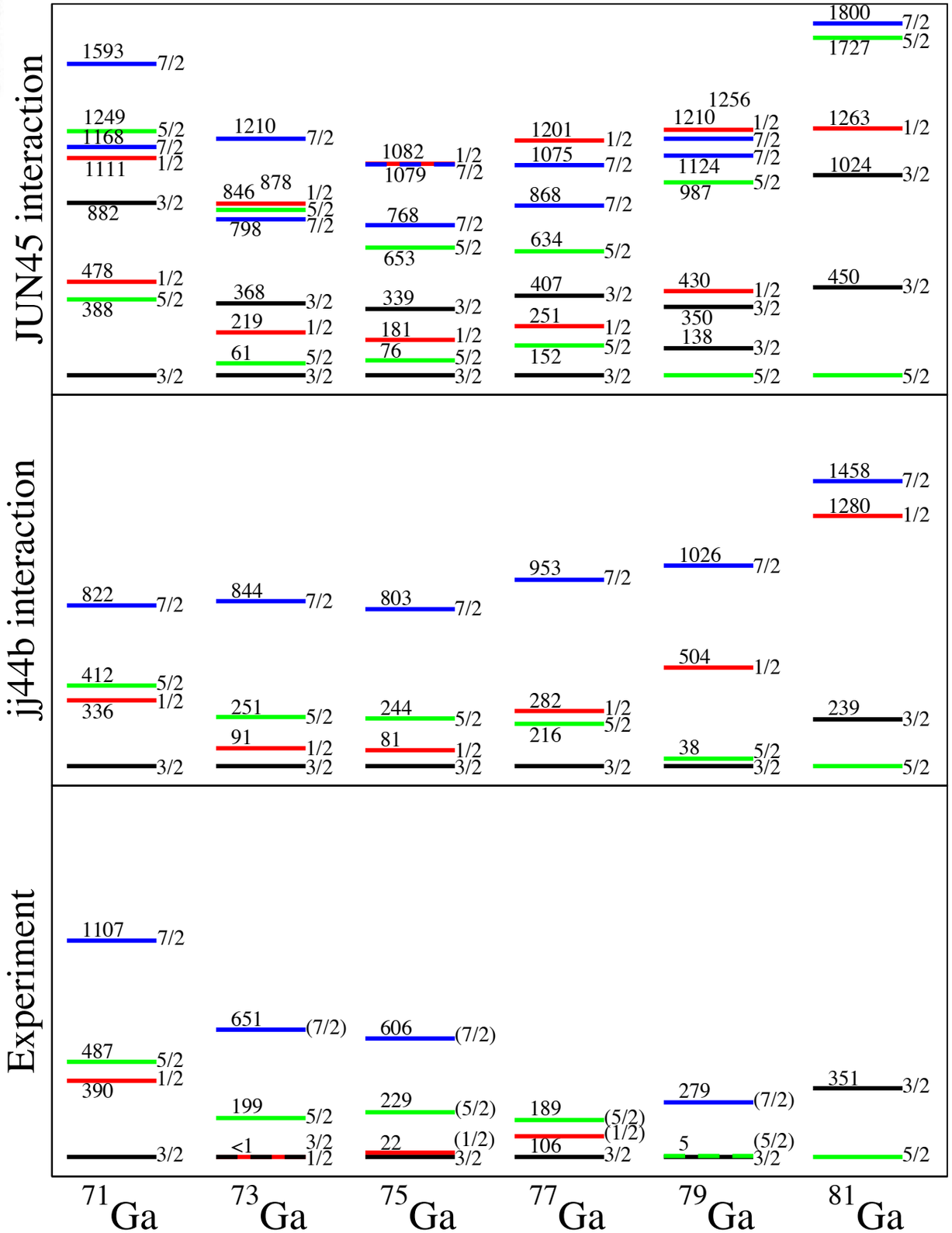
Comparison with theory (Energy)



JUN45 - M. Honma

Low *I*=1/2 state in ^{73}Ga ✔

jj44b - B.A. Brown

Spin inversion ✔

Experimental

1/2$^-$, 3/2$^-$, 5/2$^-$, 7/2$^-$

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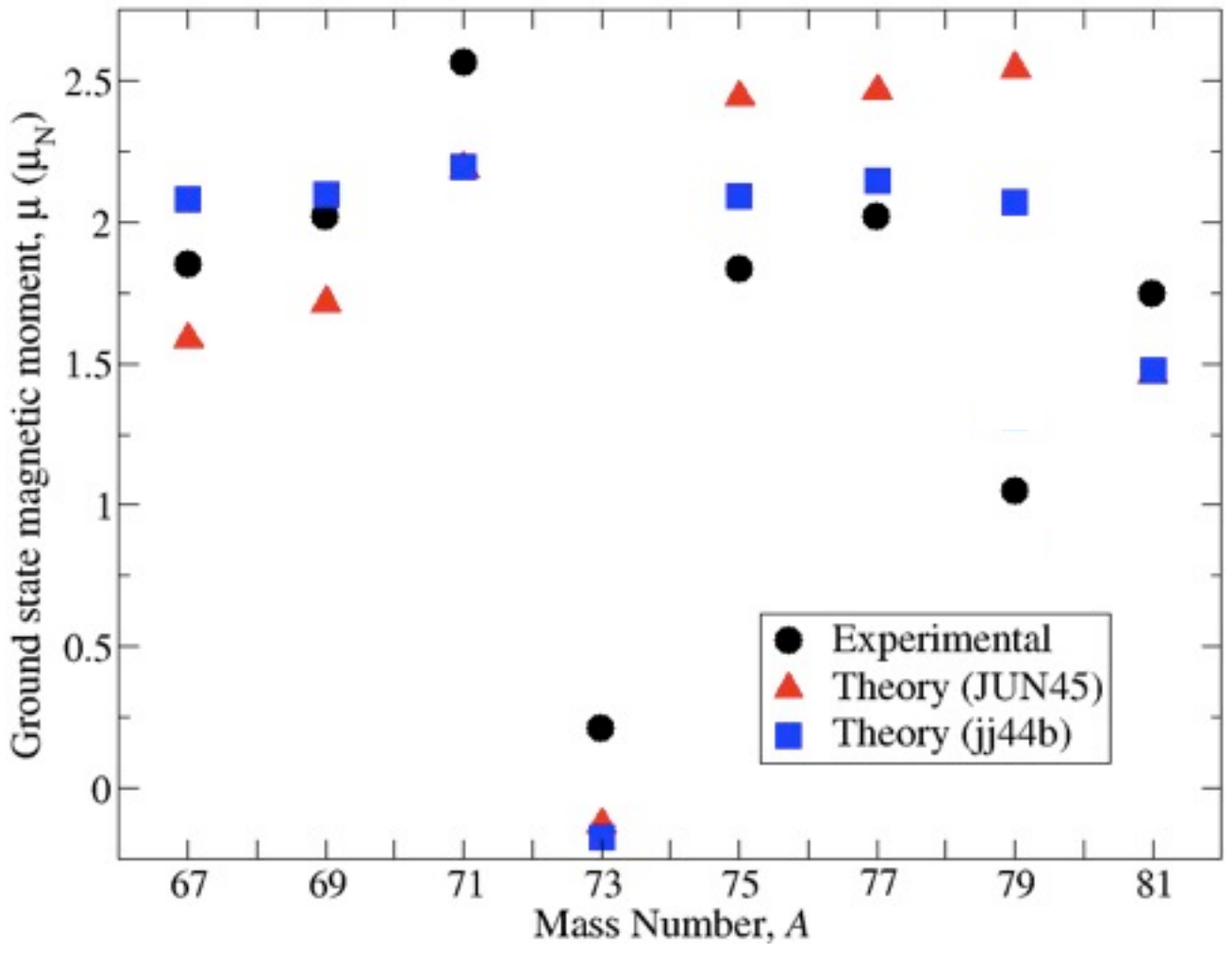
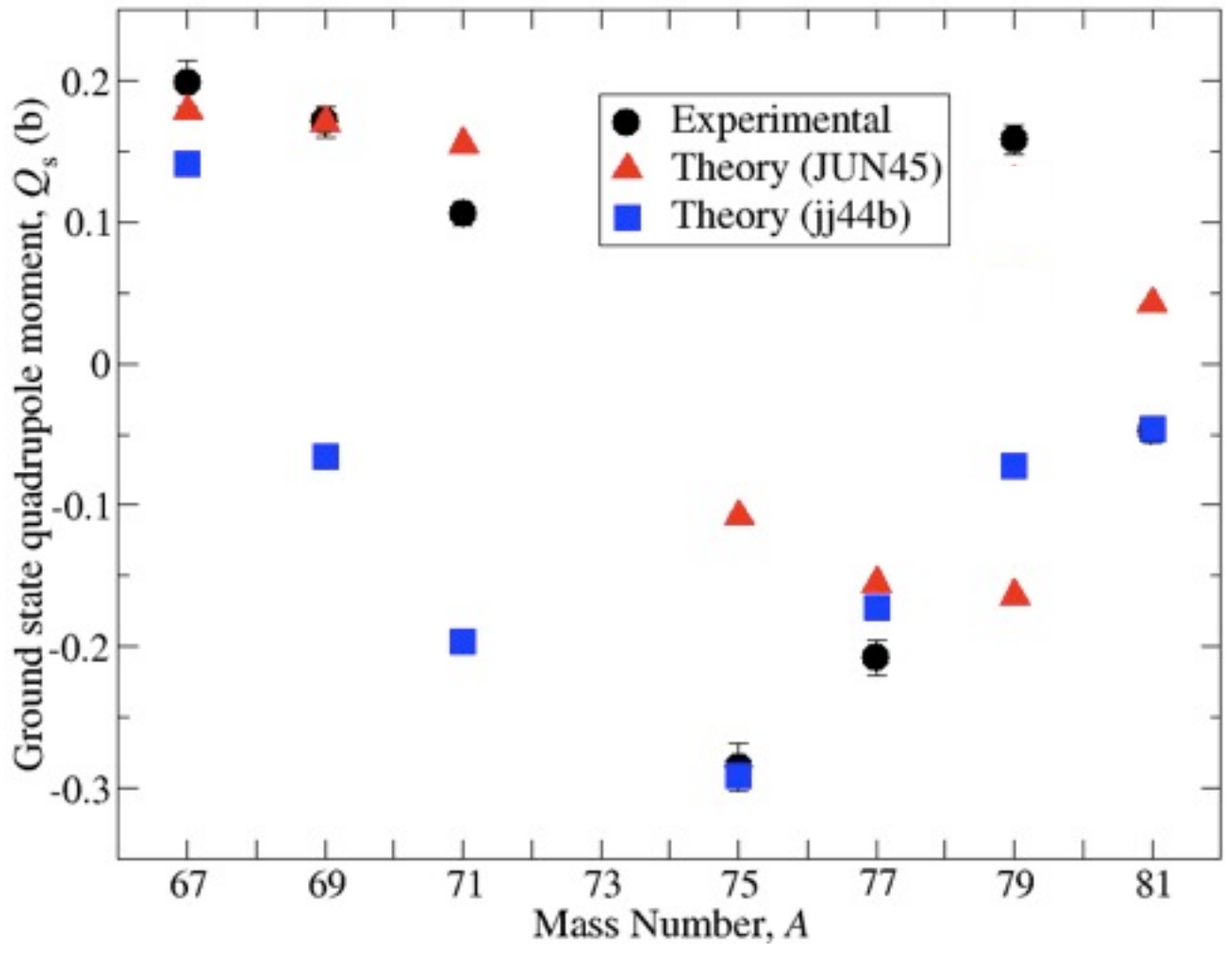
Theory - nuclear moments

Magnetic dipole



Electric quadrupole



Fails for ^{79}Ga in particular ....

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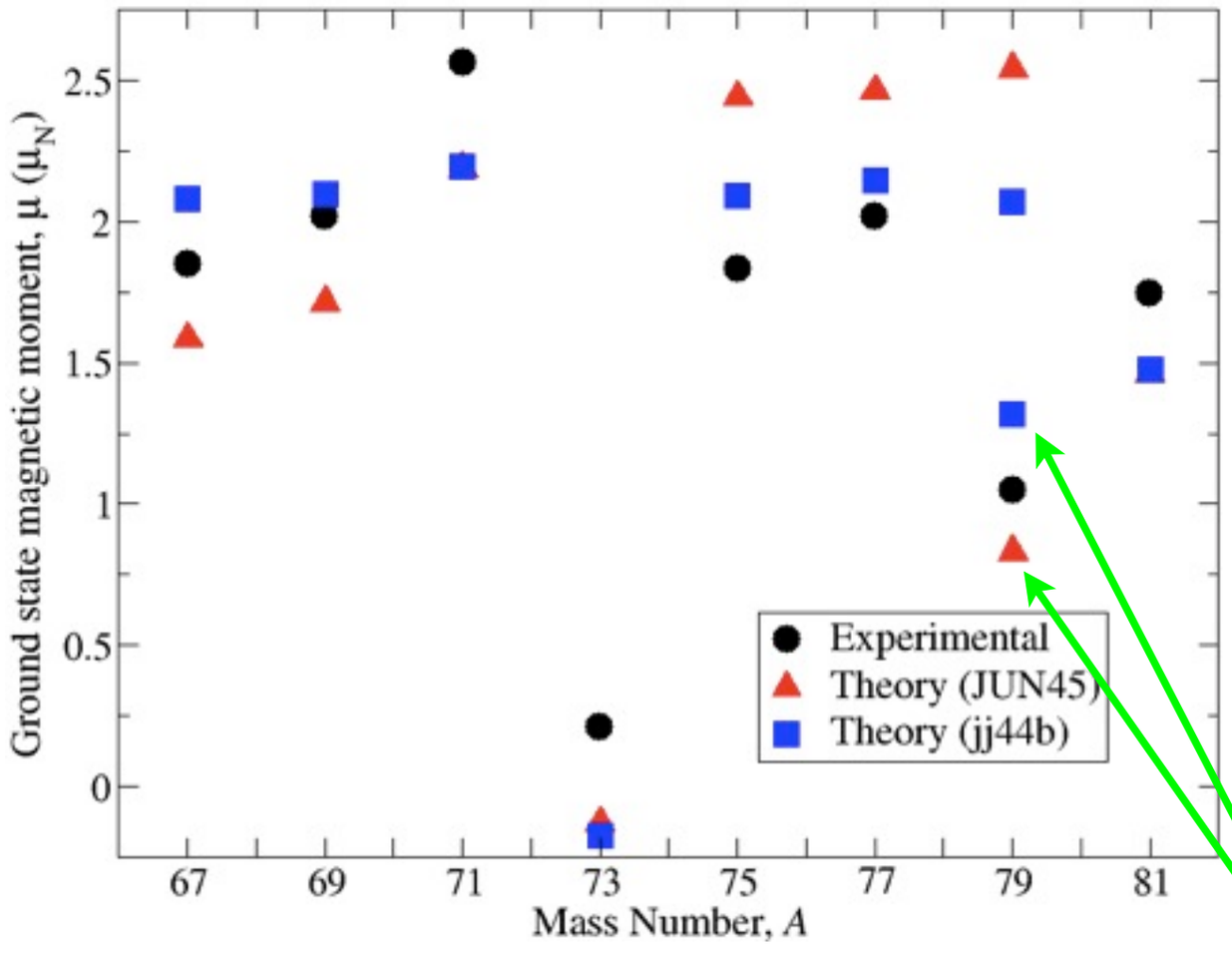
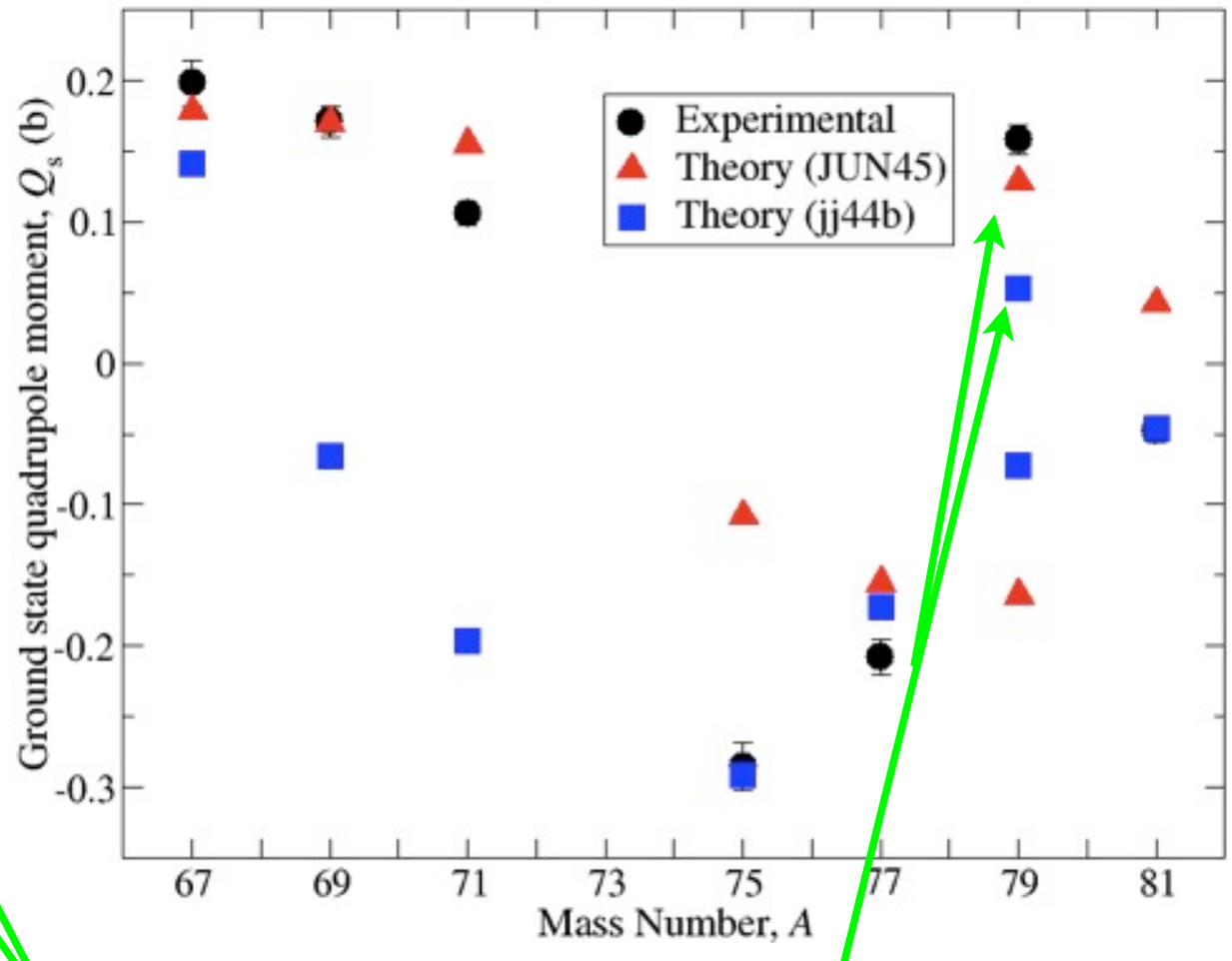
Theory - nuclear moments

Magnetic dipole



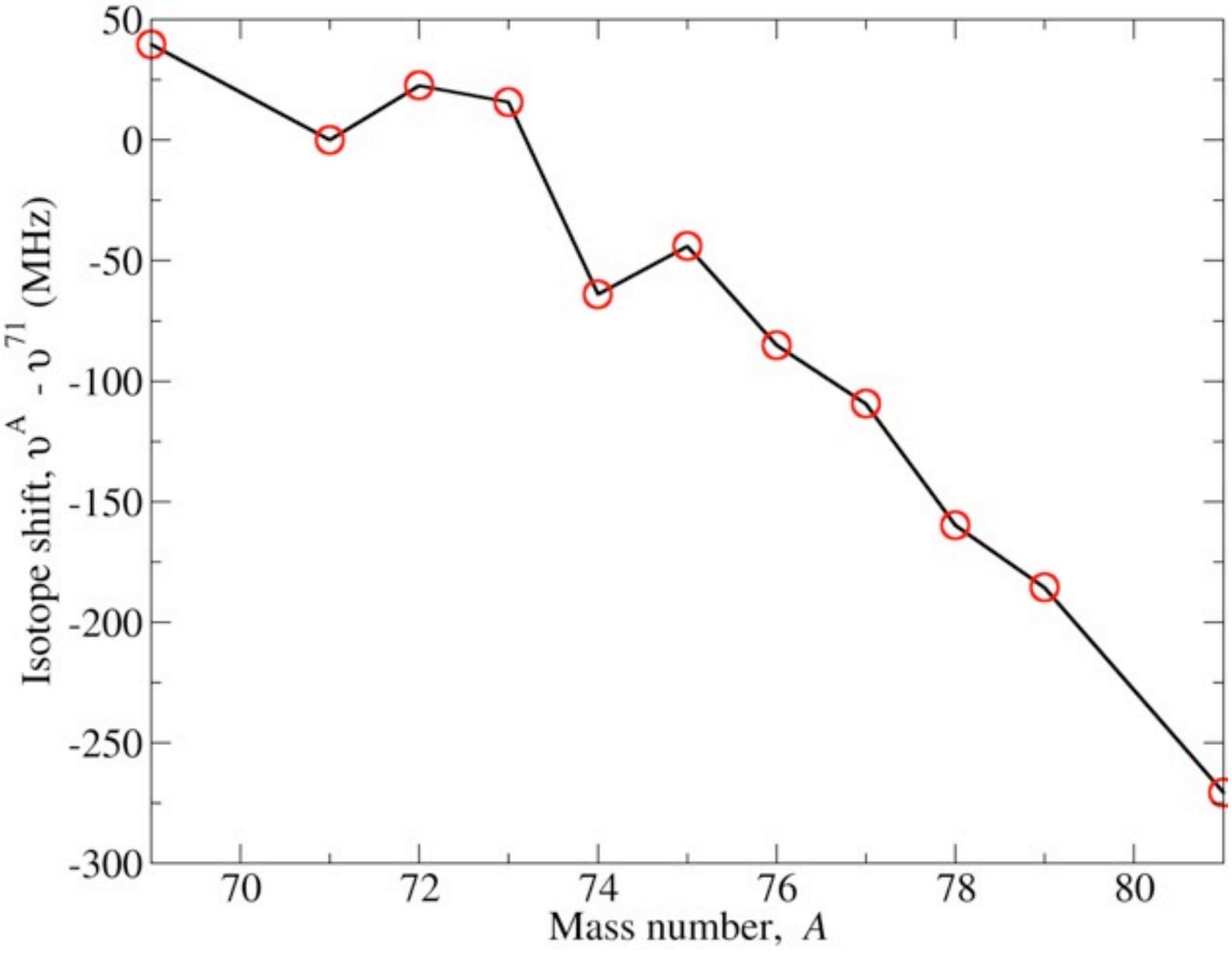
Electric quadrupole



"Second" 3/2 states

..or the gs?

Isotope shift data



Need to calculate atomic factors...

$$\delta\nu^{A,A'} = M_i \frac{A' - A}{AA'} + F_i \delta\langle r^2 \rangle^{A,A'}$$

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Summary and outlook

- Inversion seen between ^{79}Ga and ^{81}Ga
- ^{73}Ga is $I = 1/2$ (not $I = 3/2$)
- Spins also confirmed for ^{76,77,78,79,80,81}Ga

- Isomeric state discovered in ^{80}Ga

- Theoretical predictions of moments

- Analysis of charge radii data

See talk by Pieter Vingerhoets (Cu) isotopes

Collaborating institutions

Manchester, UK
KU Leuven, Belgium
Birmingham, UK
ISOLDE, CERN
Jyväskylä, Finland
Orsay, France
Heidelberg, Germany
Mainz, Germany
New York, USA

Beta_2 values

67	+0.16
69	+0.13
71	+0.08
75	-0.25
76	+0.17
77	-0.18
78	+0.17
79	+0.12
81	-0.02