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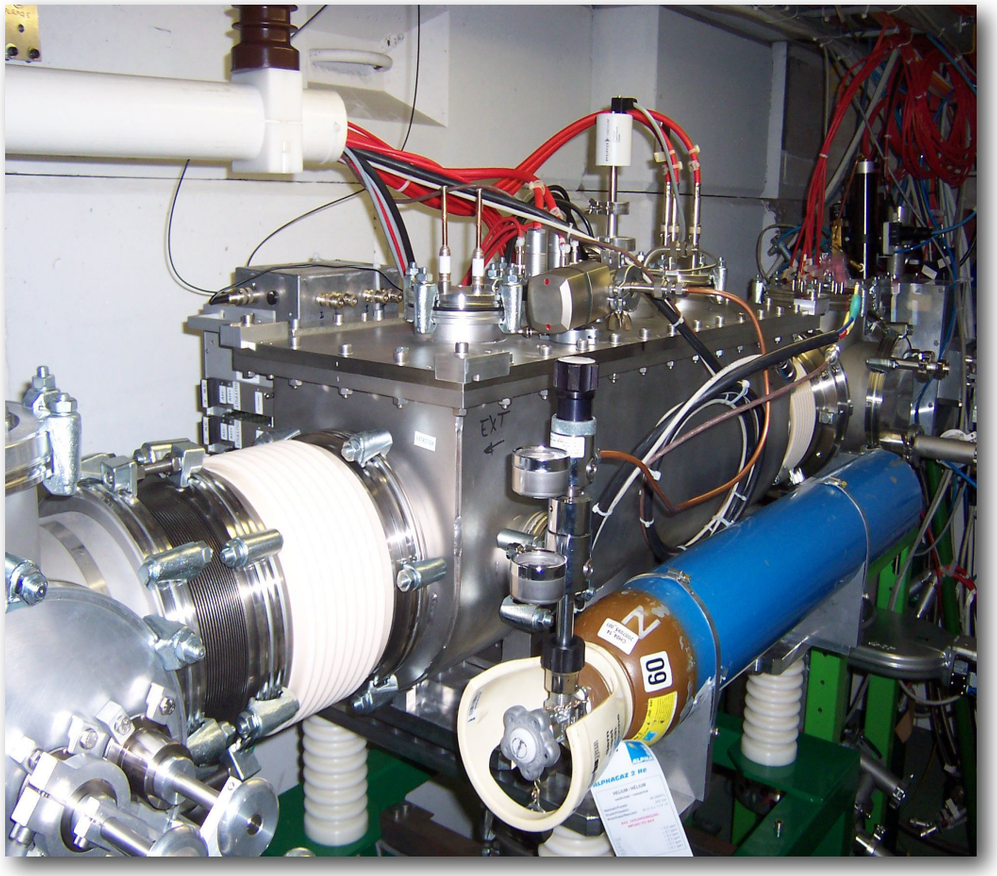
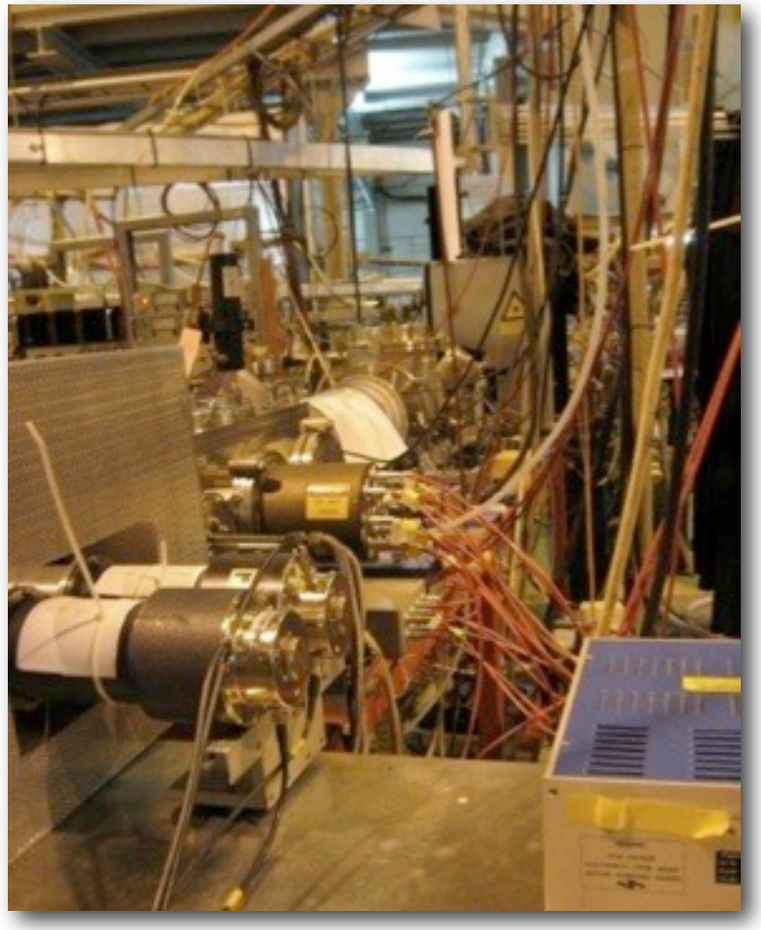
Laser spectroscopy of gallium isotopes using ISCOOL





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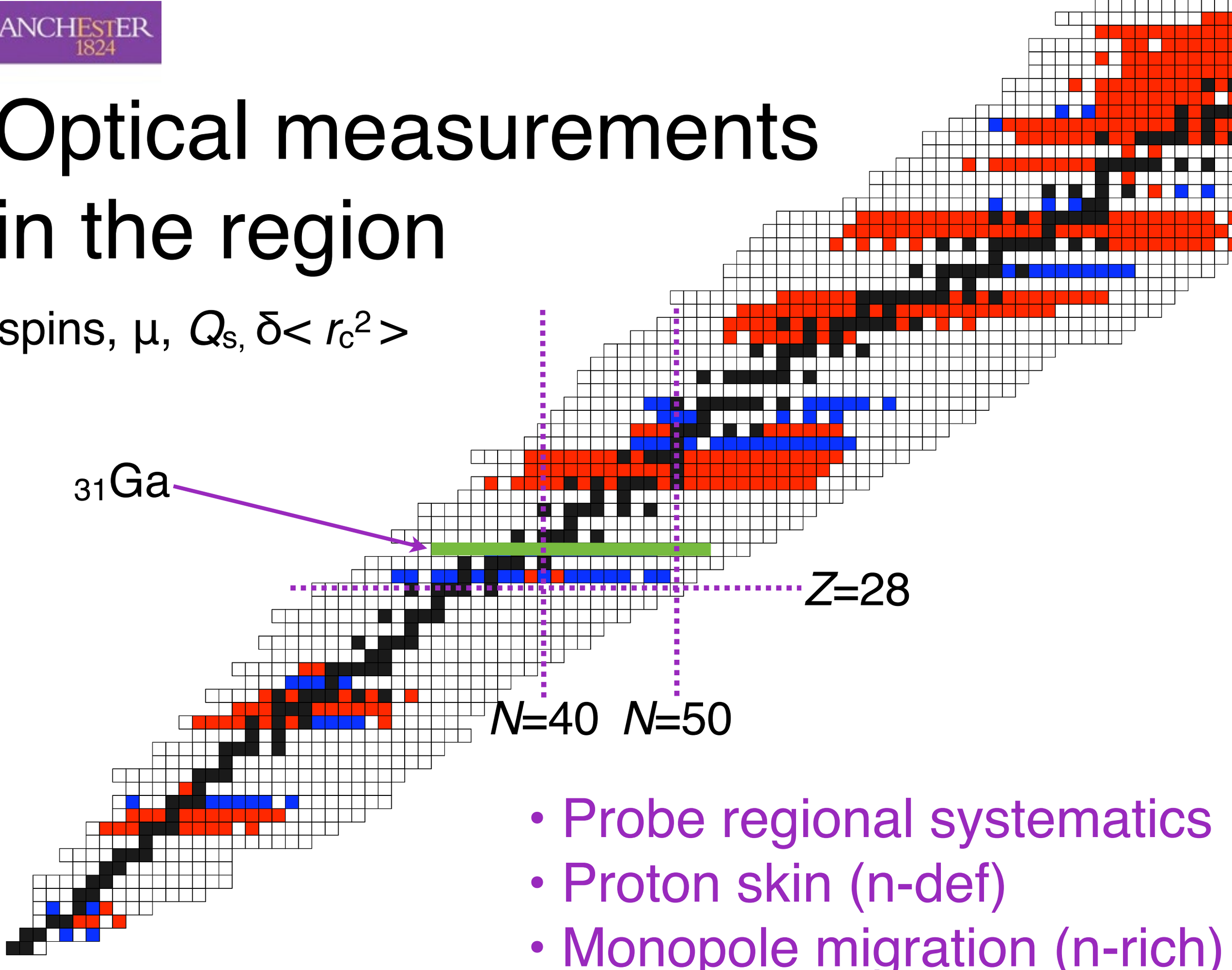
Optical measurements in the region

→ spins, μ, Q_s, δ< r_c^2 >



- Probe regional systematics
- Proton skin (n-def)
- Monopole migration (n-rich)

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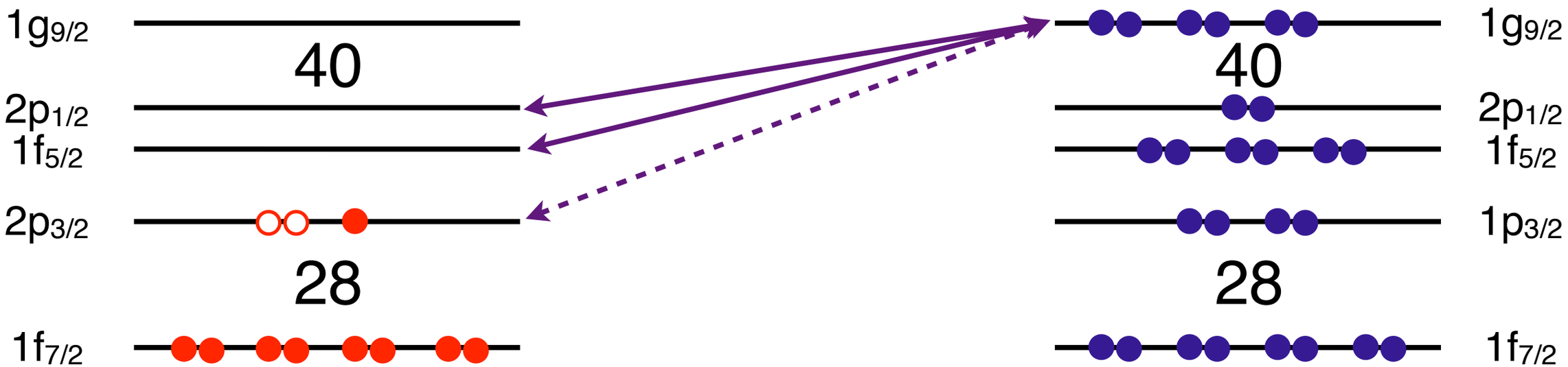
Physics motivation (n-rich)

Otsuka (PRL 95 232502):-

Tensor force **attractive** between J=L+1/2 and J=L-1/2
(otherwise **repulsive**)



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

Use laser spectroscopy to measure the gs spins...

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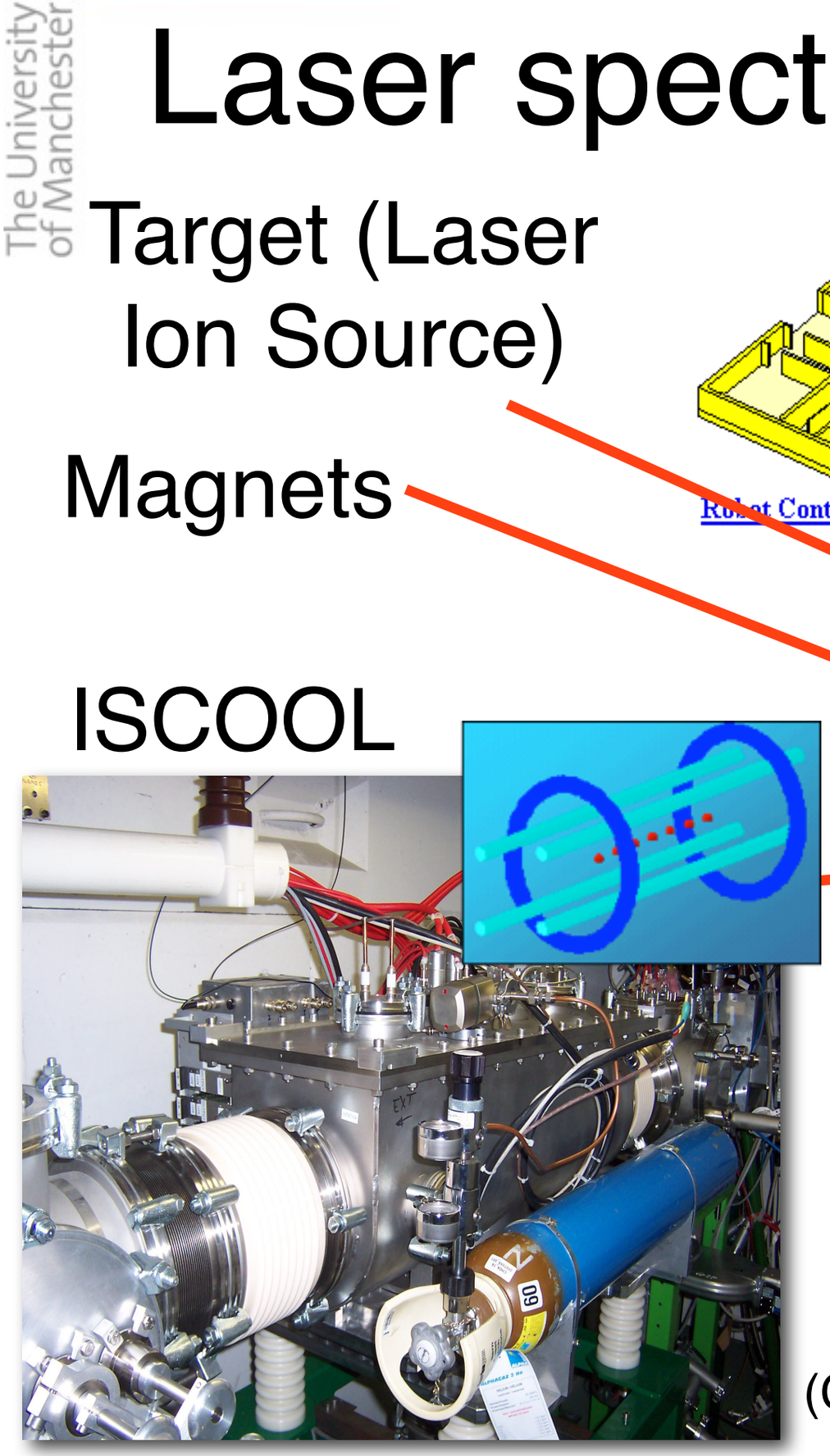
Laser spectroscopy at ISOLDE

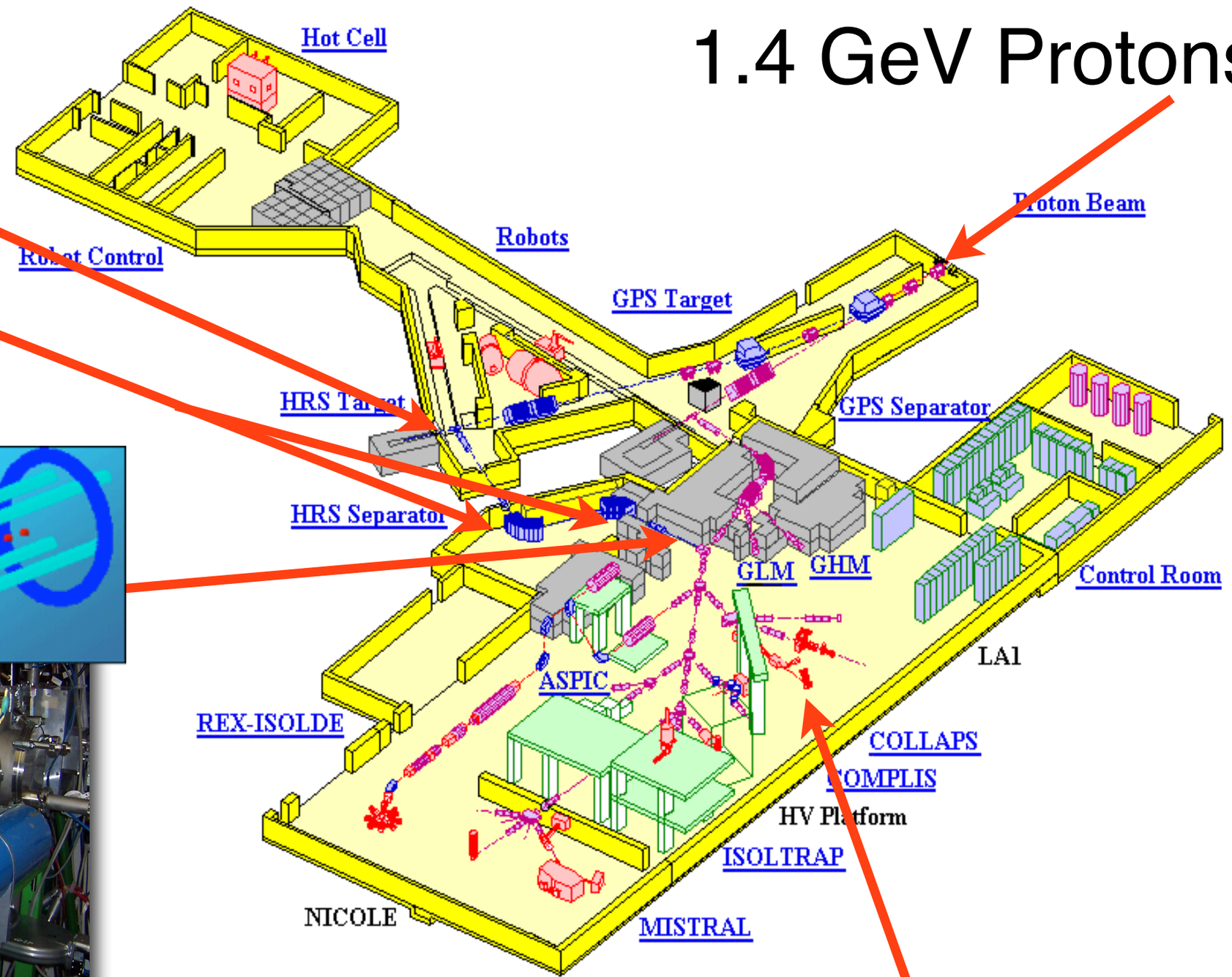
Target (Laser Ion Source)

Magnets

ISCOOL



(Gas filled RFQ)



1.4 GeV Protons

Spectroscopy

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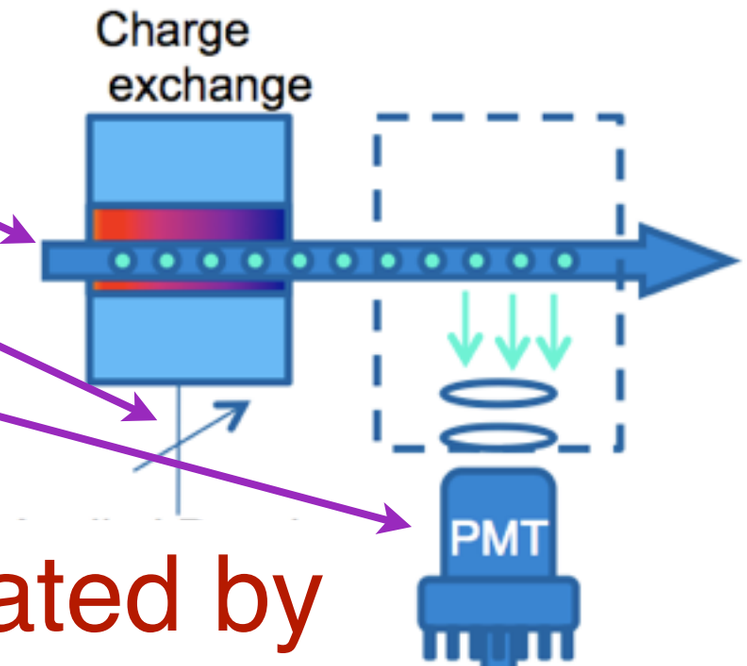
Laser spectroscopy with ISCOOL

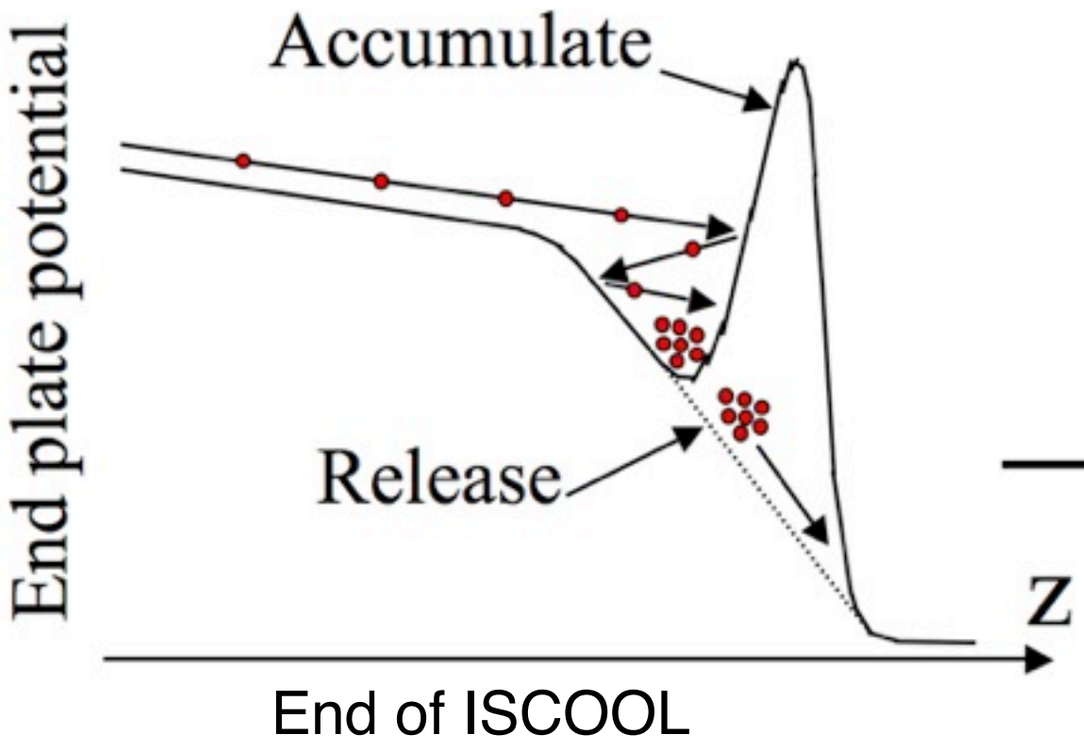
Collinear laser-atom beams

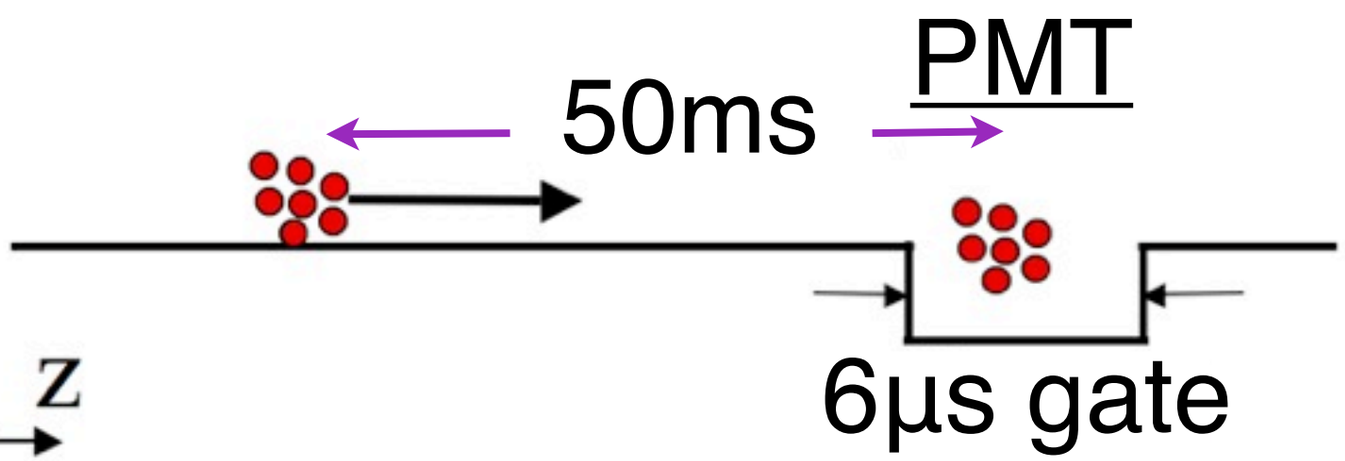
Doppler tuning potential

Photon detection



Photon background dominated by continuous laser scatter





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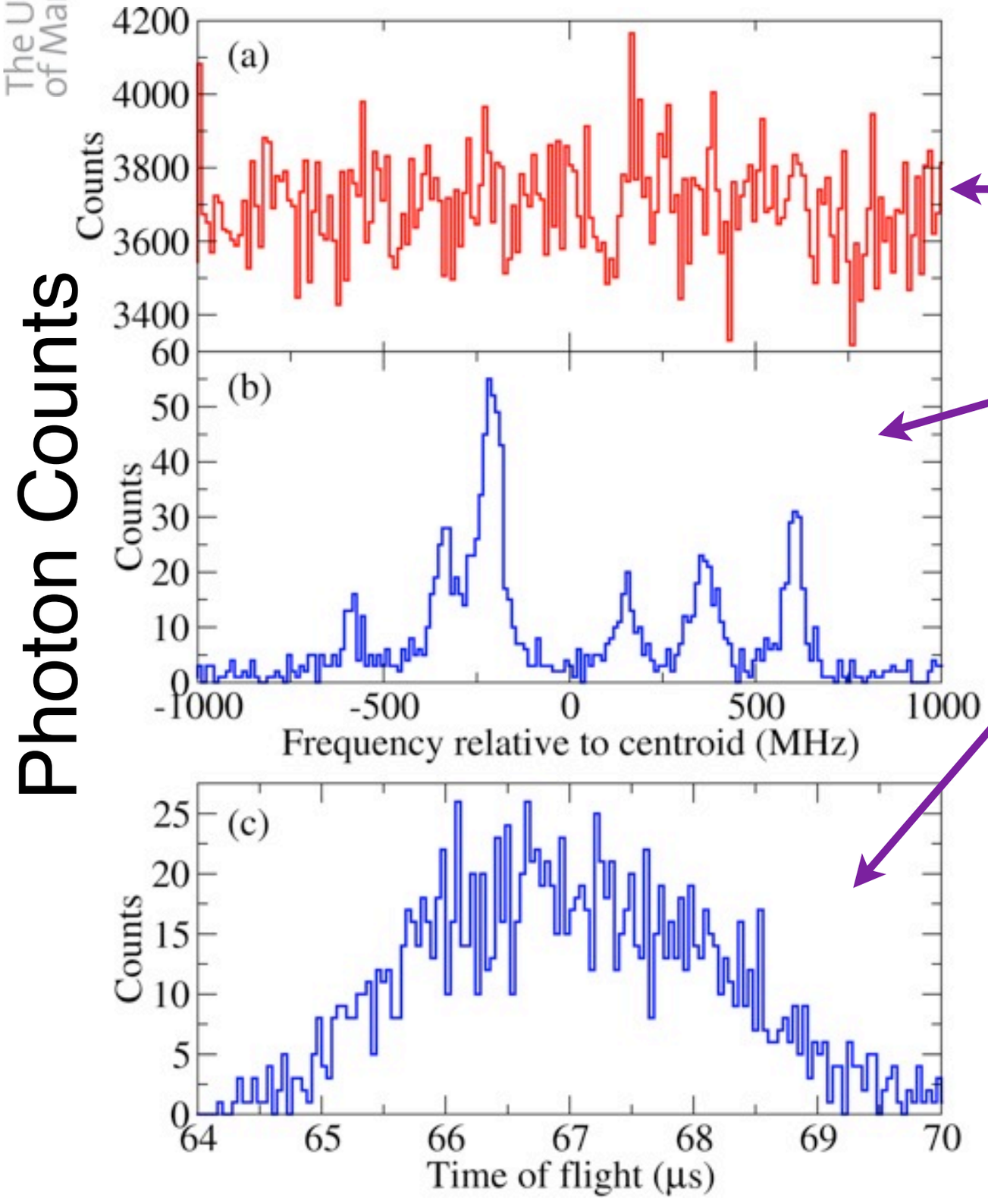
Example spectrum - ^{76}Ga



Ungated

Gated (64μs - 70μs)

Time of flight
(50ms accumulation)

<u>Background suppression</u>

50ms / 6μs = ~10^4

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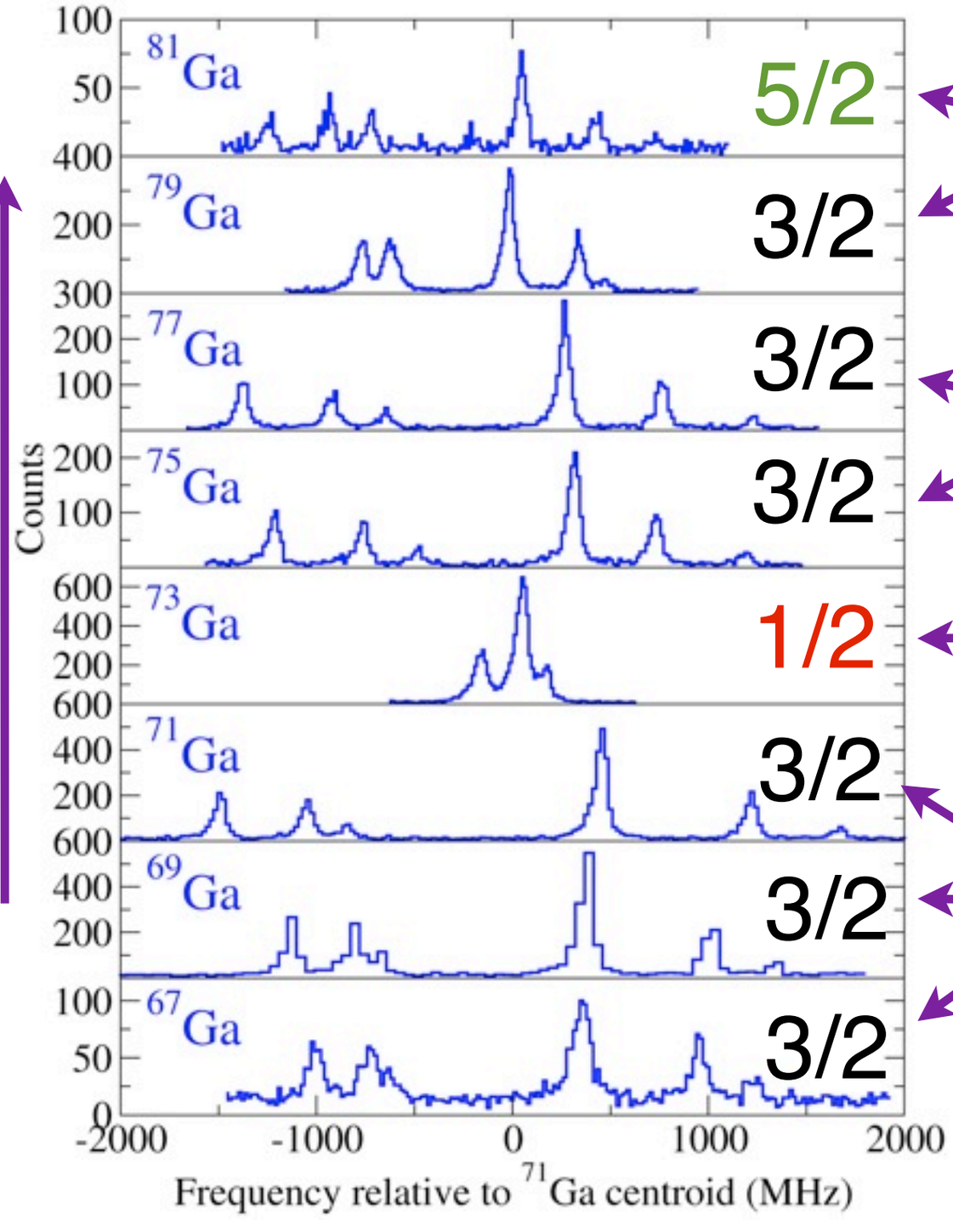
417nm Ga I spectra

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



Emptying of $p_{3/2}$

Spin 3/2, 5/2 inversion

Q_s -ve

Spin 1/2 col.

Q_s +ve

$\pi\ p_{3/2}(f_{5/2})^2$

similar g-factors

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

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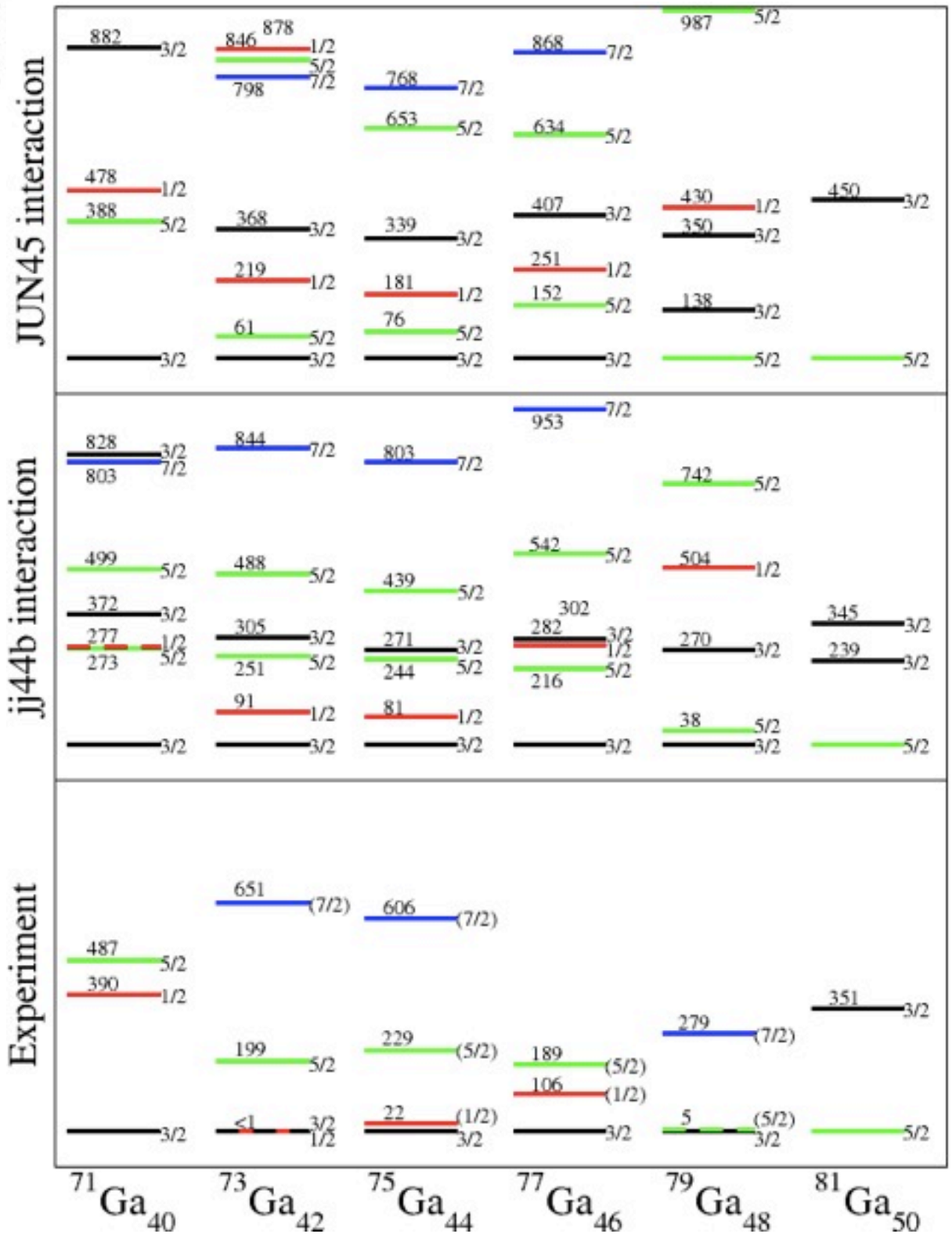
Theory - energy levels



Shell model calculations,
2 effective interactions:-

- JUN45
- jj44b

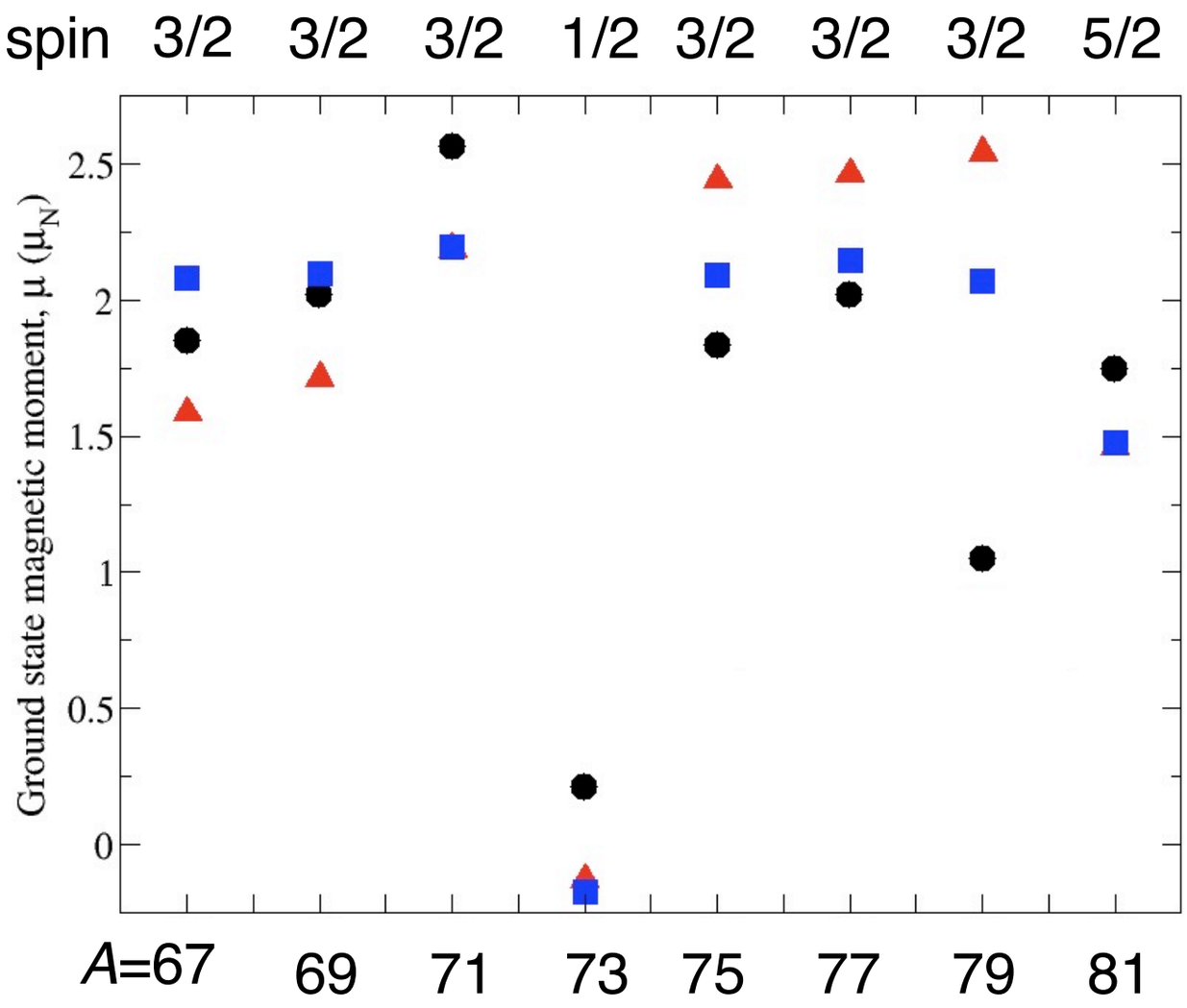
1/2$^-$, 3/2$^-$, 5/2$^-$, 7/2$^-$

jj44b - spin inversion

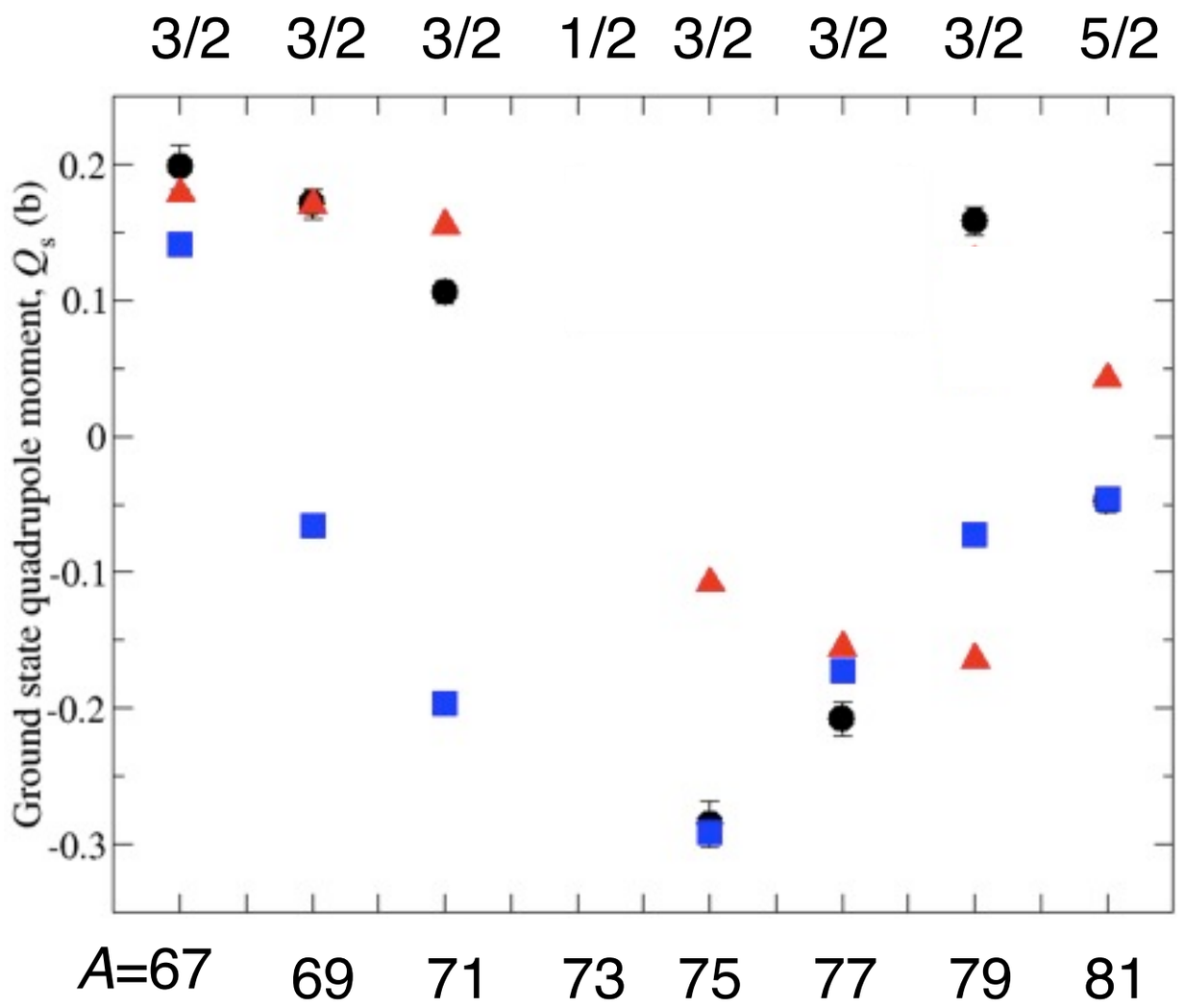
Fail to predict ^{73}Ga (I=1/2)

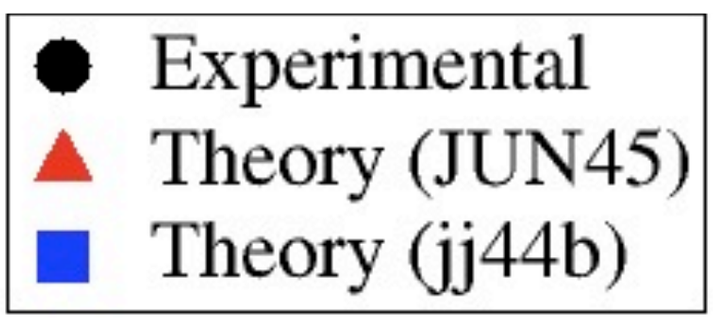
Theory - nuclear moments

Magnetic dipole



Electric quadrupole





Poor match for ^{79}Ga

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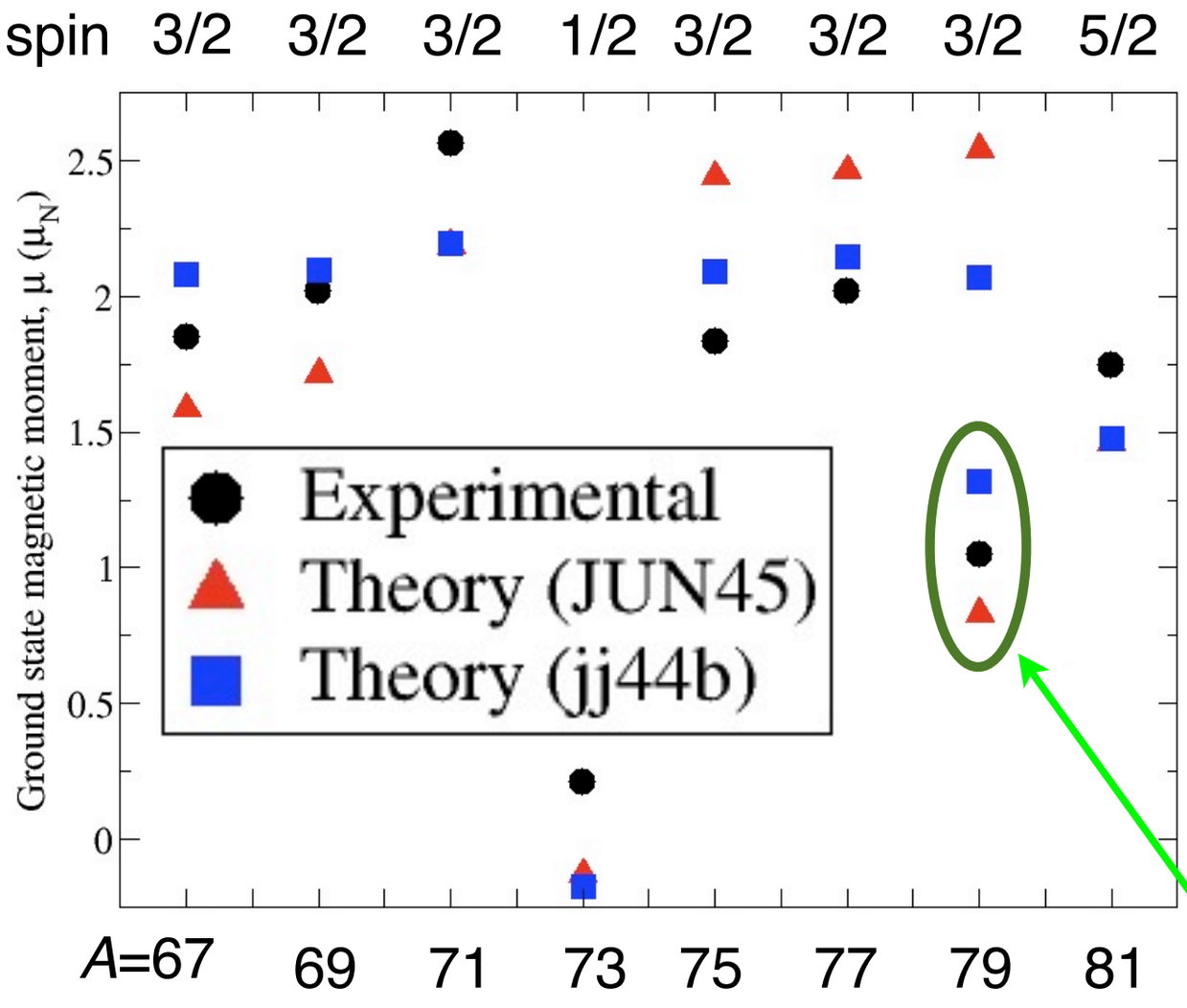
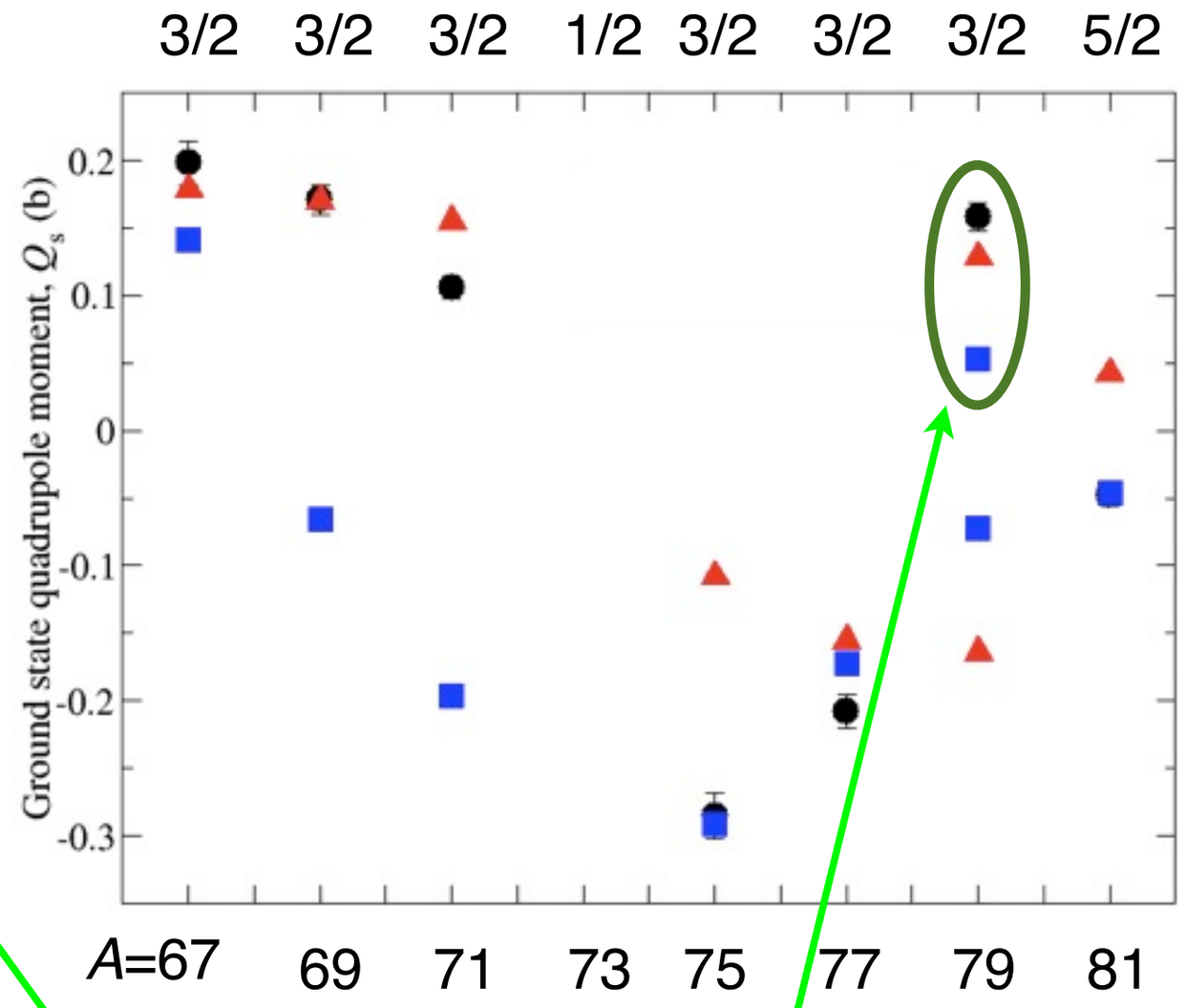
Theory - nuclear moments

Magnetic dipole



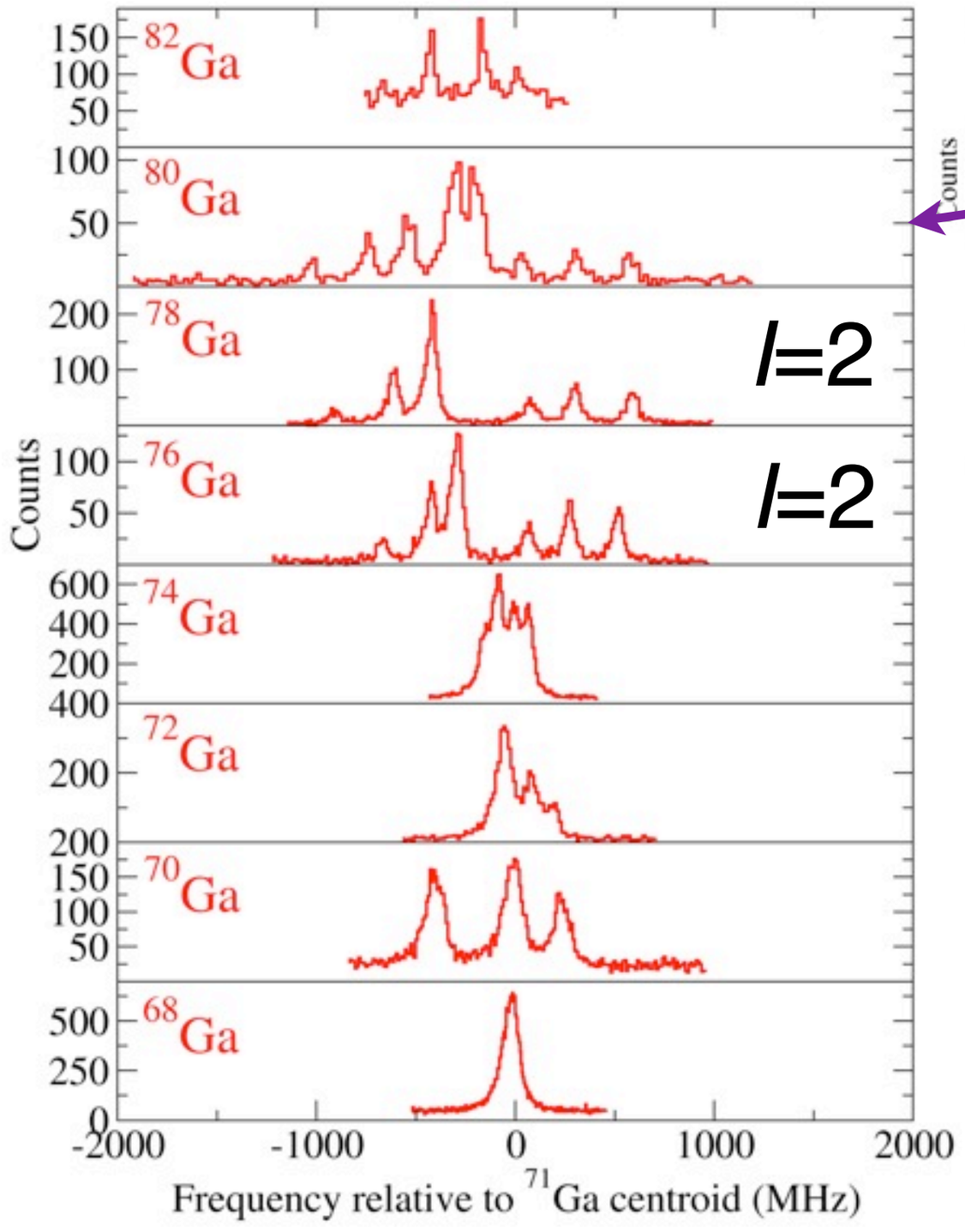
Electric quadrupole



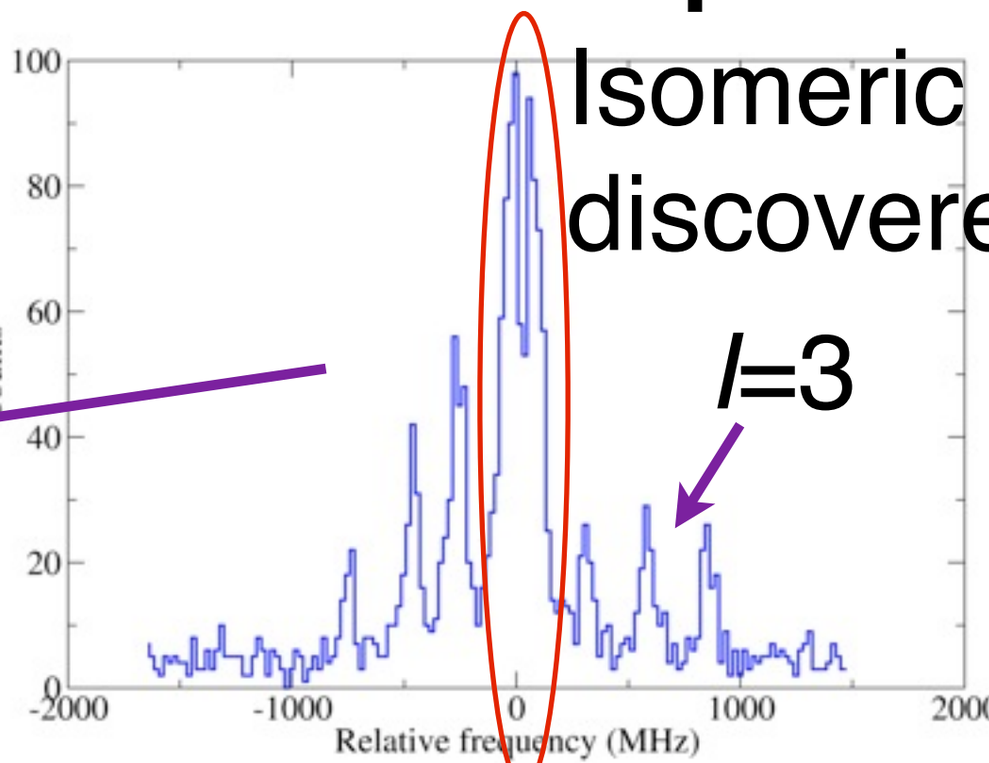
Predictions for **second** 3/2 states (300 keV)

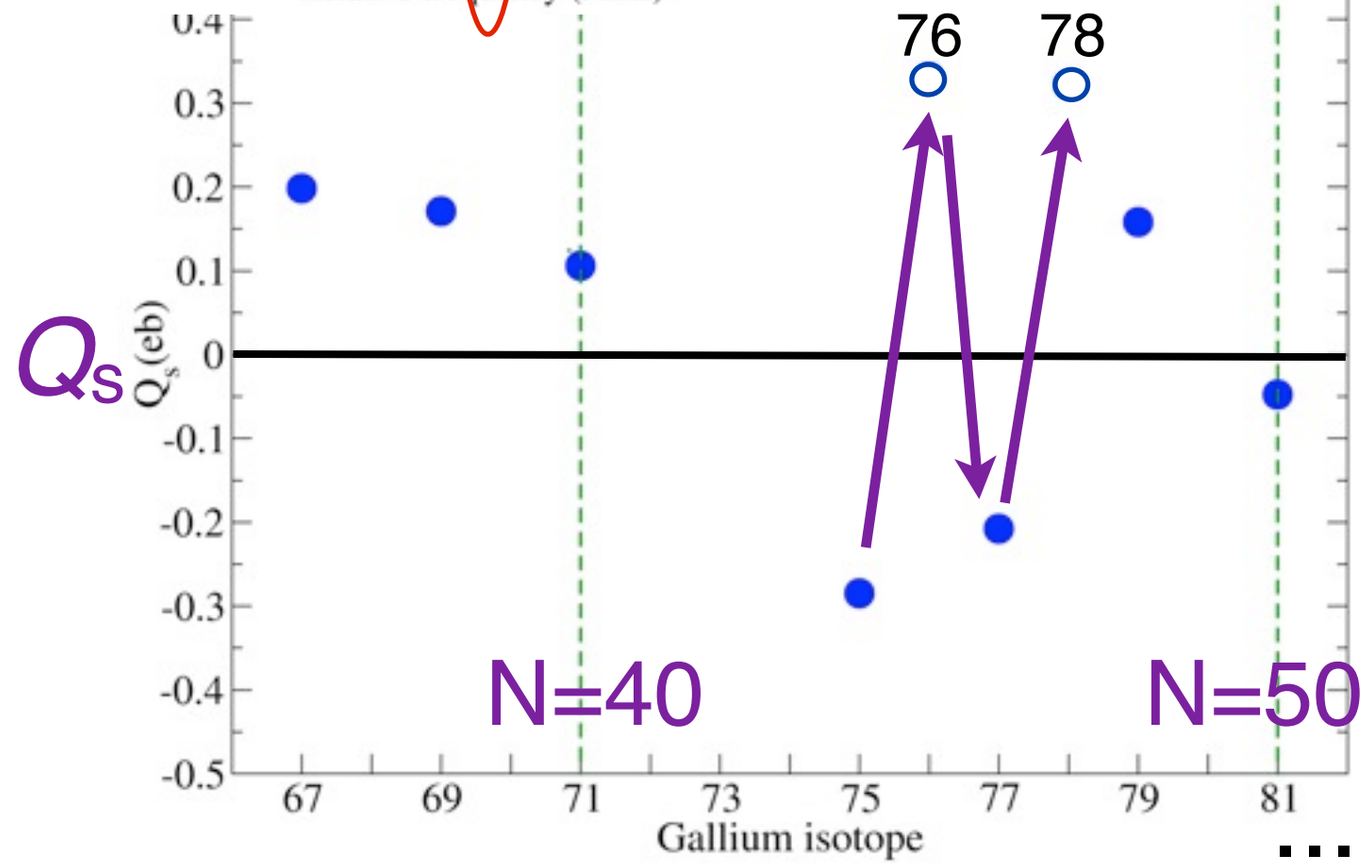
It is these which match gs properties ($f^3_{5/2}$ dominated)

Odd-odd Ga isotopes



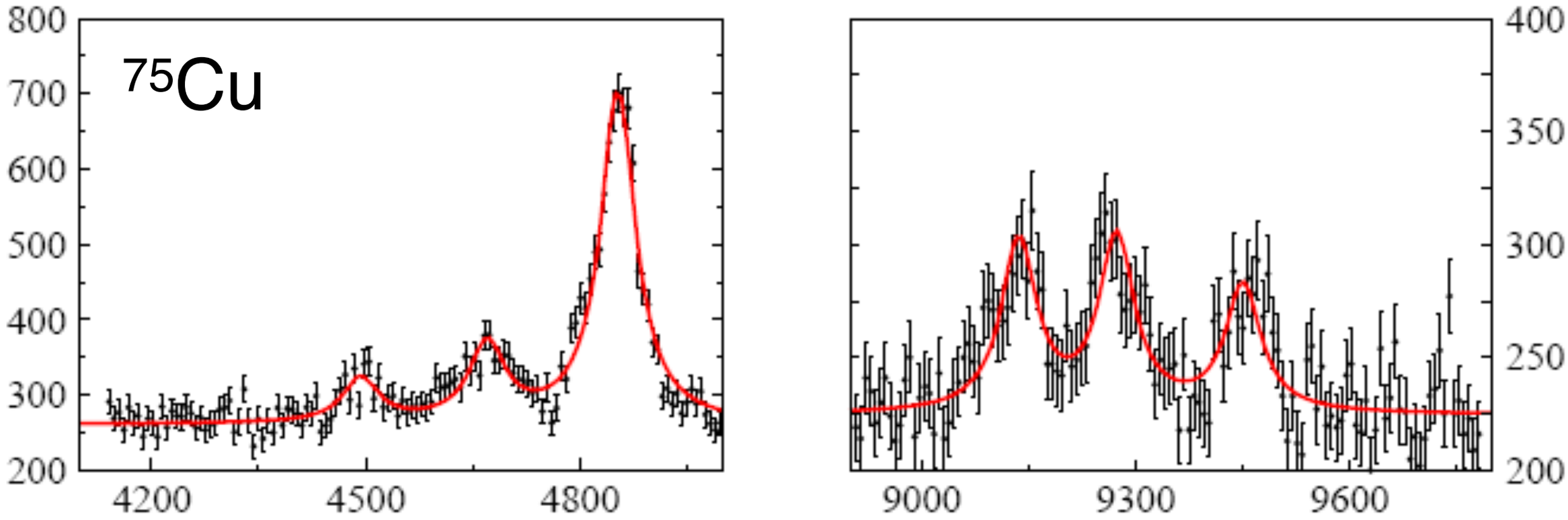
Isomeric state discovered in ^{80}Ga



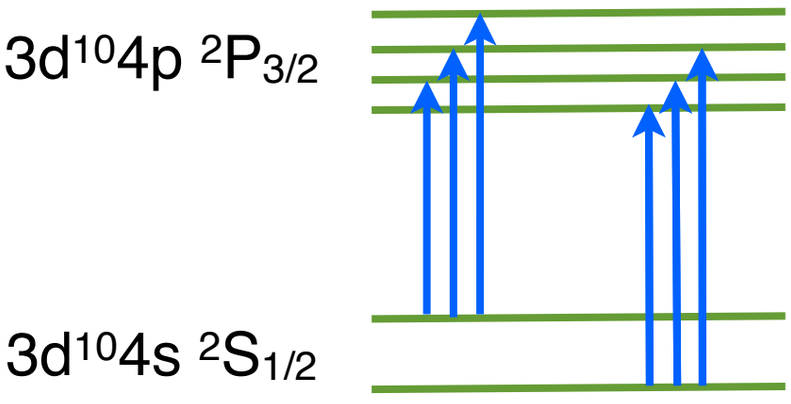


....

Inversion in copper



K.T. Flanagan *et al.* PRL 103,142501 (2009)



(odd) $^{59\text{-}73}$Cu are I=3/2
but: ^{75}Cu is I=5/2

Inversion between N=44,46 (Cu)
N=48,50 (Ga)

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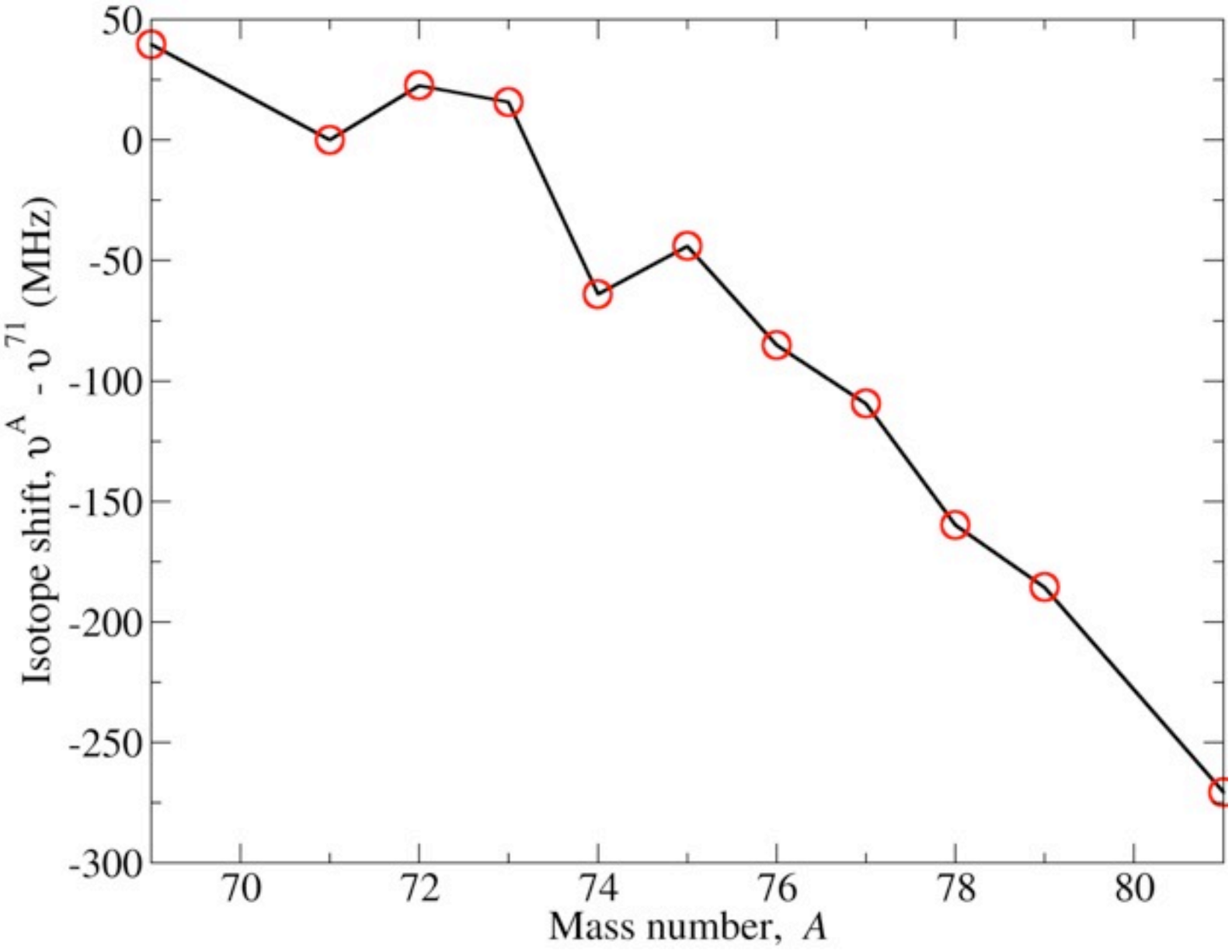
Isotope shift data



Need to calculate atomic factors...

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

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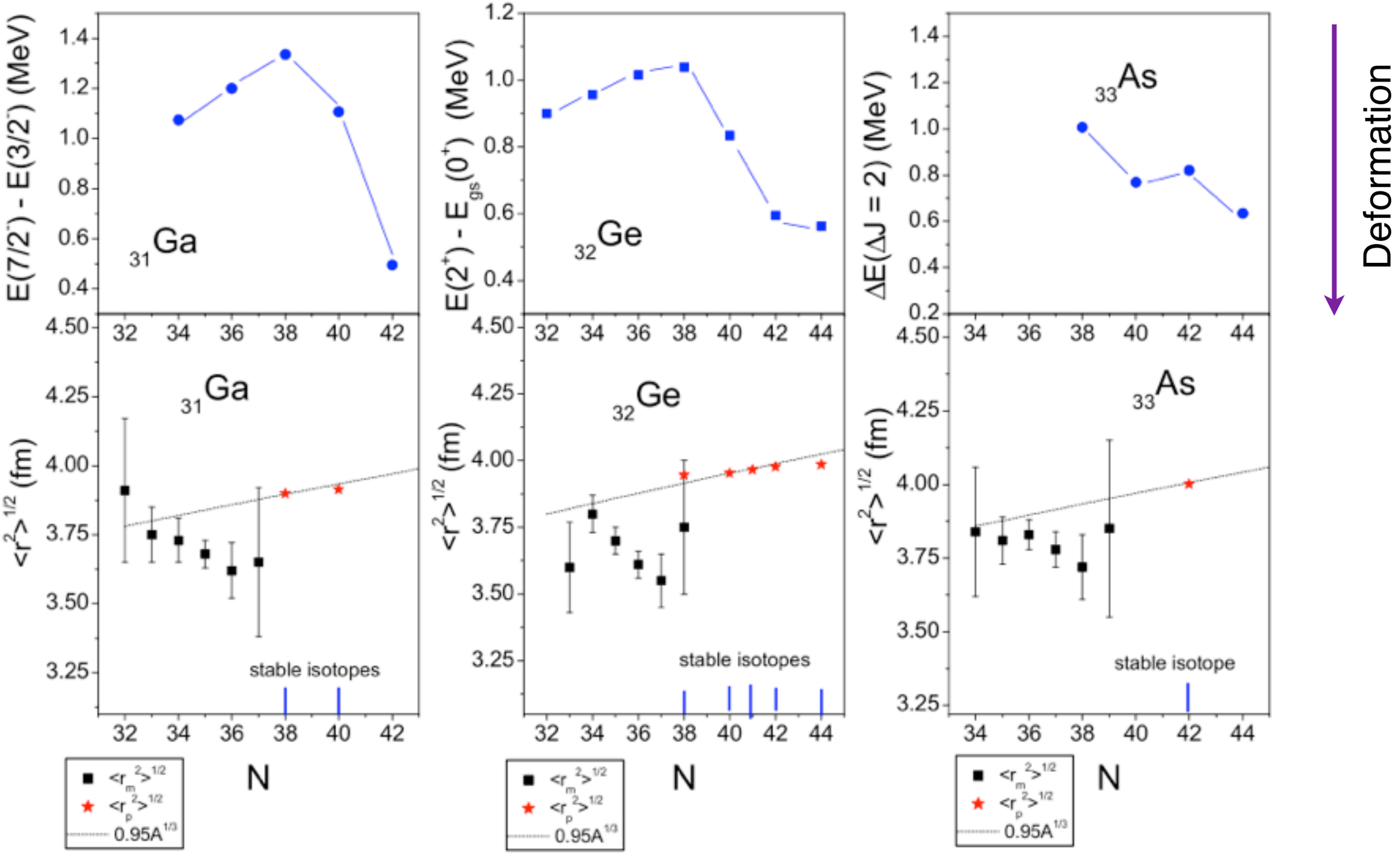
Case for neutron-deficient study

A. Lépine-Szily *et al.*
Eur. Phys. J. A. **25**, s01, 227 (2005)



Matter radii *increase* with decreasing neutron number

➔ Suggest formation of a proton skin ➔ $\delta\langle r_c^2\rangle$ ➔ IS.

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In conclusion...

- Commissioned ISCOOL
  - Critically suppresses photon background

- Measured n-rich spins, moments, isotope shifts
  - Spin inversion due to monopole migration
  - Gradual emptying of proton $p_{3/2}$ → $f_{5/2}$ domination
  - ^{73}Ga has anomalous spin of I=1/2

- Will study of $^{62\text{-}69}$Ga
  - Measure charge radii (proton skin?)

Accepted for publication in PRL (odd-*A* isotopes)

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