

Spins and moments of cooled and bunched n -rich Ga isotopes:

First (**preliminary**) results using the ISCOOL-COLLAPS apparatus

Ernesto Mané

ISOLDE workshop and users meeting 2008

Ga-1S451

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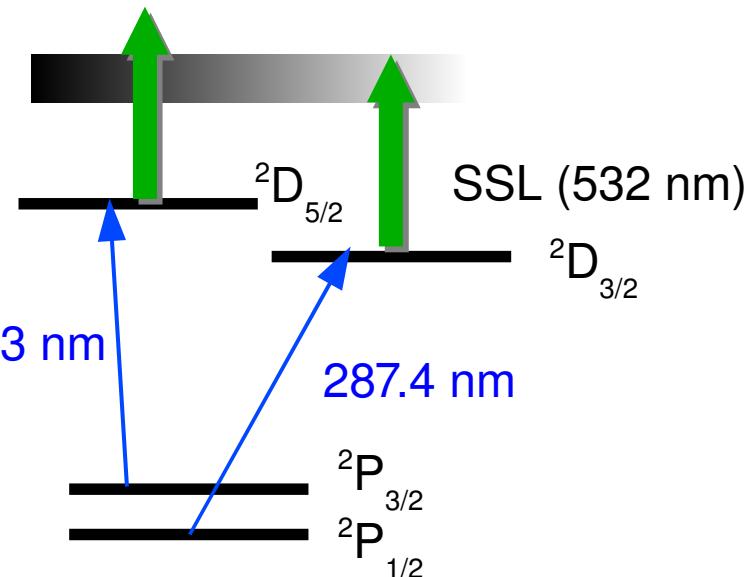
^{67}Ga $J\pi=3/2^-$	^{68}Ga $J\pi=1^+$	^{69}Ga $J\pi=3/2^-$	^{70}Ga $J\pi=1^+$	^{71}Ga $J\pi=3/2^-$	^{72}Ga $J\pi=3^-$	^{73}Ga $J\pi=3/2^-$	^{74}Ga $J\pi=(3^-)$	^{75}Ga $J\pi=3/2^-$	^{76}Ga $J\pi=(2+, 3+)$	^{77}Ga $J\pi=(3/2^-)$	^{78}Ga $J\pi=(3+)$	^{79}Ga $J\pi=(3/2^-)$	^{80}Ga $J\pi=(3)$
^{66}Zn $J\pi=0+$	^{67}Zn $J\pi=5/2^-$	^{68}Zn $J\pi=0+$	^{69}Zn $J\pi=1/2^-$	^{70}Zn $J\pi=0+$	^{71}Zn $J\pi=1/2^-$	^{72}Zn $J\pi=0+$	^{73}Zn $J\pi=(1/2)^-$	^{74}Zn $J\pi=0+$	^{75}Zn $J\pi=(7/2+)$	^{76}Zn $J\pi=0+$	^{77}Zn $J\pi=(7/2+)$	^{78}Zn $J\pi=0+$	^{79}Zn $J\pi=(9/2+)$

Previous Knowledge (Stone 2005)

Isotope	I^π	$\mu(\text{nm})$	$Q_s(b)$	
67	$3/2^-$	+1.8507(3)	0.195(5) st	(no sign)
68	1^+	0.01175(5)	0.0277(14) st	
69	$3/2^-$	+2.01659(5)	+0.17(3) st	
70	1^+	-	-	
71	$3/2^-$	+2.56227(2)	+0.106(3) st	
72	3^-	-0.13224(2)	+0.52(1) st	
73	$3/2^-$	-	-	
74	(3)	-	-	
75	$3/2^-$	-	-	
76	(2,3)	-	-	
77	$3/2^-$	-	-	
78	(3)	-	-	
79	$(3/2^-)$	-	-	
80	(3)	-	-	

...and no IS, apart from $\Delta\nu^{69,71}$

RILIS scheme for Ga (eff ~ 21%)



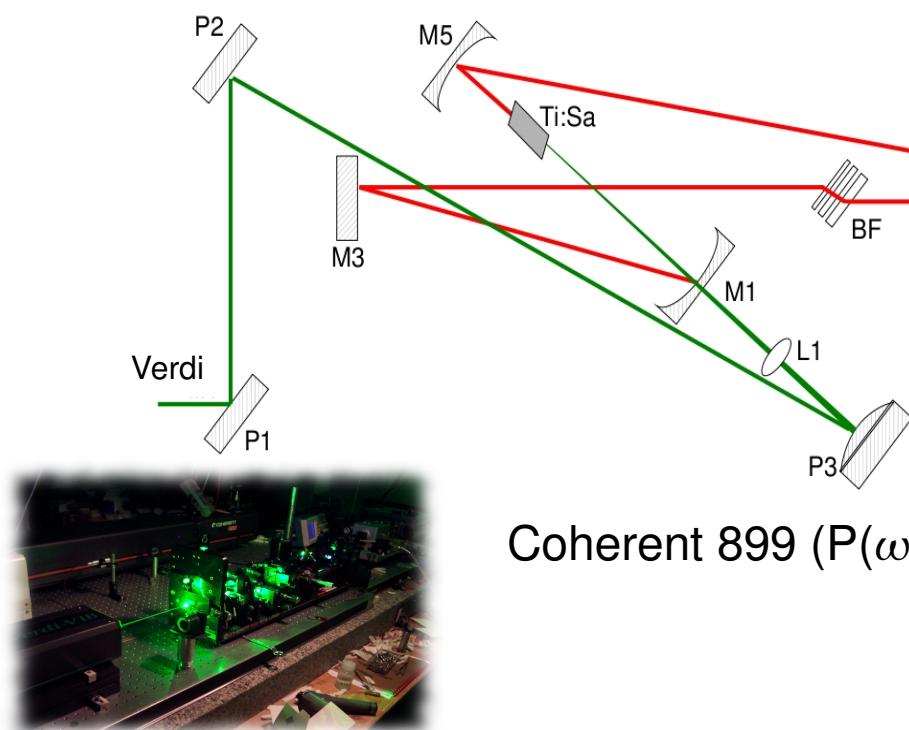
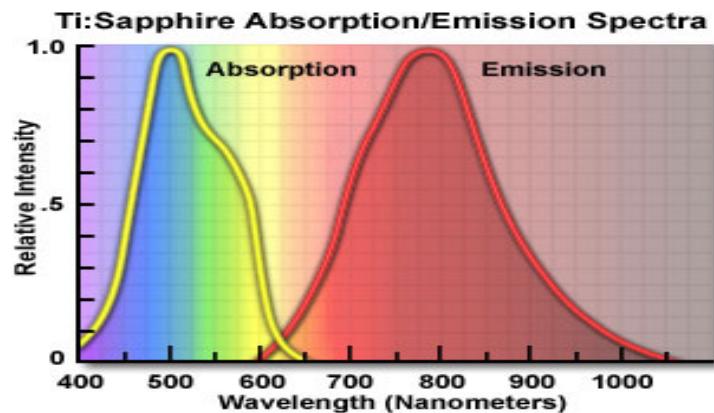
HRS @ 50 kV

ISCOOL @ 49.916 kV ; RF 360KHz, amplitude 420V_{p-p}

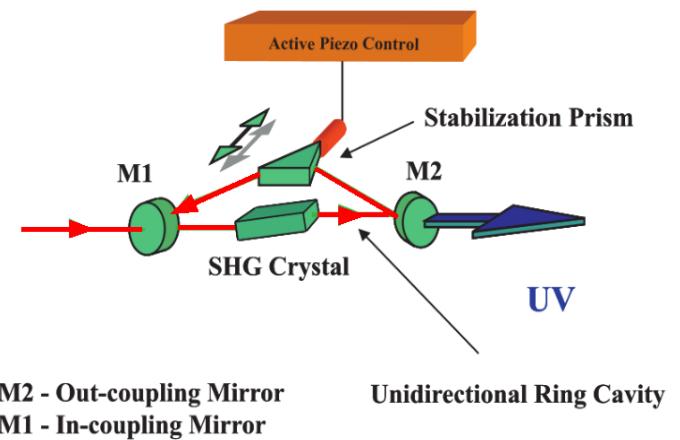
∀ masses (transmission ~ 70% in continuous)

Bunching: Acc times **10-50 ms**, bunch width **20-25 μs**

Experimental apparatus: The COLLAPS laser



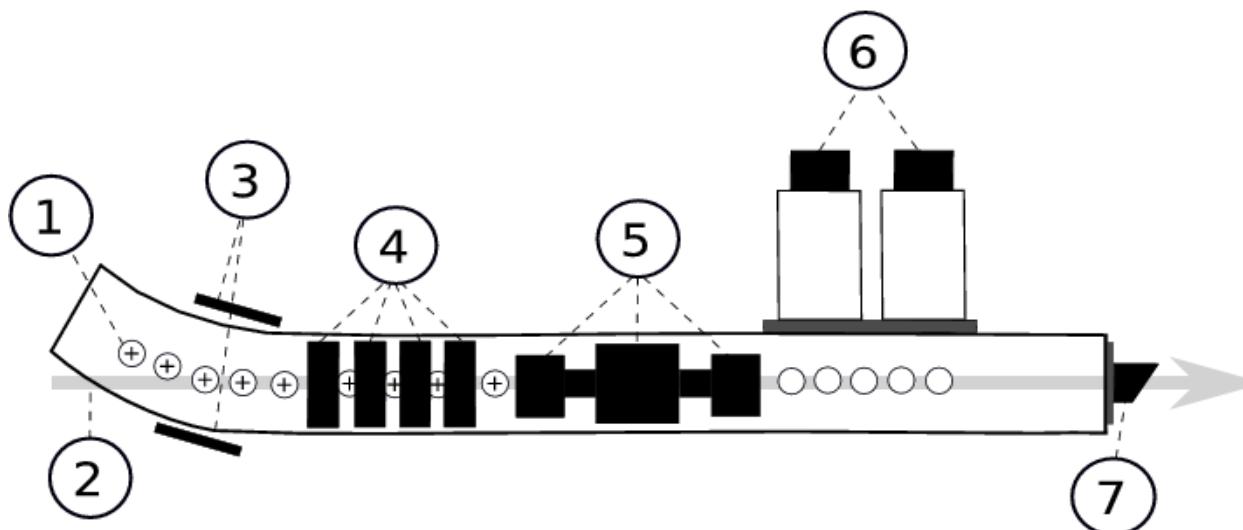
Coherent 899 ($P(\omega) \sim 1\text{W}$)



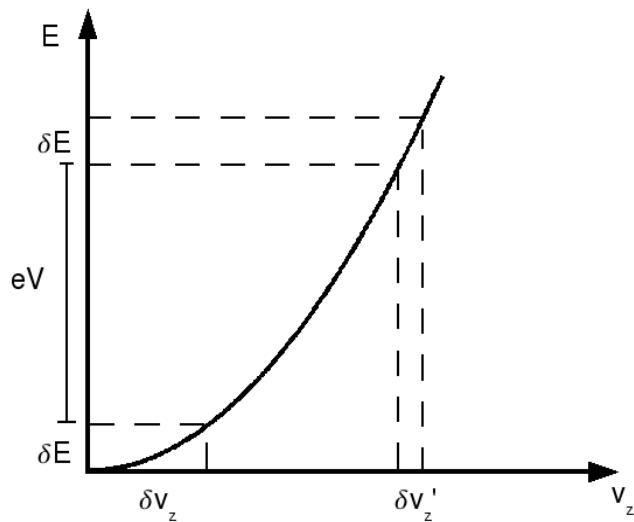
Wavetrain Delta cavity
 $P(2\omega) \sim 0.3\text{-}1.5\text{ mW}$

- External temperature controlled etalon for short term drifts
- Wavelength was monitored with wavemeter (acc $\sim 3\text{MHz}$)

"Classical" collinear technique with LIF



- 1) Single charged ions
- 2) Laser
- 3) Deflector plates
- 4) Retardation plates
- 5) Charge exchange cell
- 6) Photomultiplier tubes
- 7) Brewster window



$$E = \frac{1}{2} m v_z^2$$

$$\delta E = m v_z \delta v_z = \text{cte}$$

The "laser" scan

The laser is fixed to ν_0 and the ions are Doppler tuned as a function of V applied on retardation plate. **The technique is limited by continuous laser scatter.**

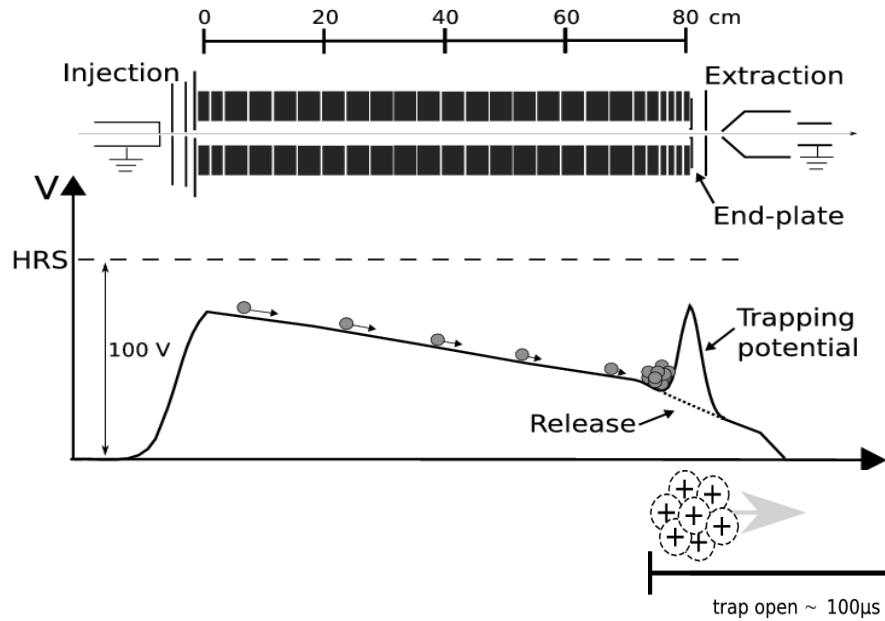
Typical flux of 10^6 atoms/s is needed

$$\nu = \nu_0 \frac{1 \pm \beta}{\sqrt{1 - \beta^2}}$$

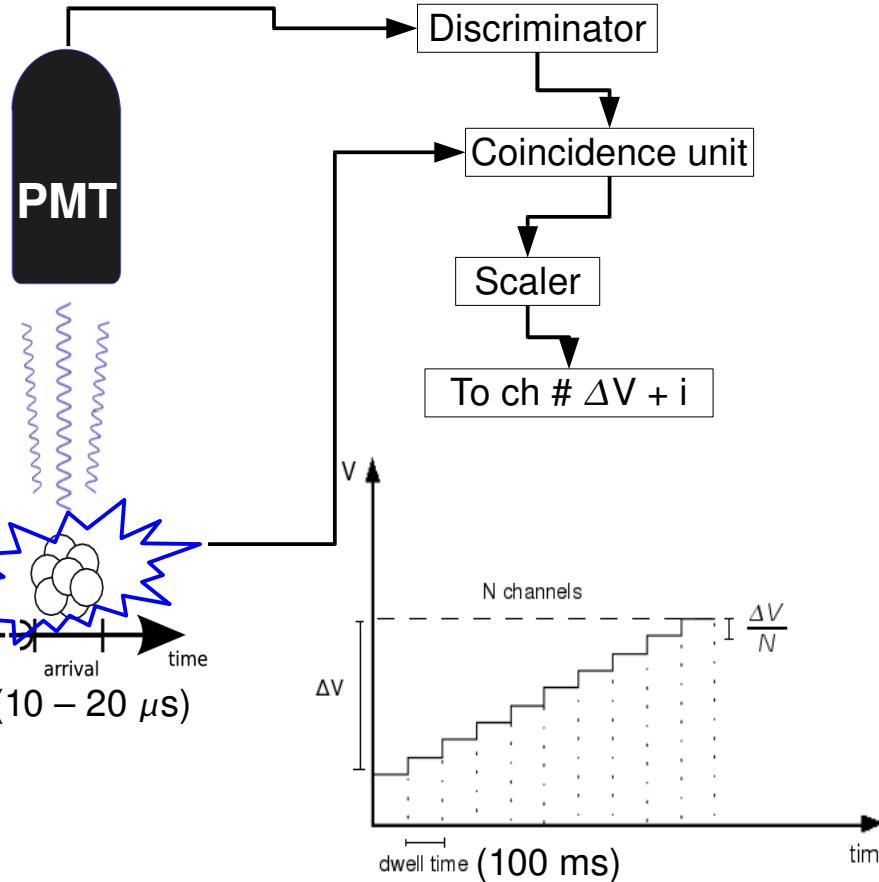
$$\beta = \sqrt{1 - \frac{M_O^2 c^4}{(UQ + M_O c^2)^2}}$$

Bunched-Beam technique

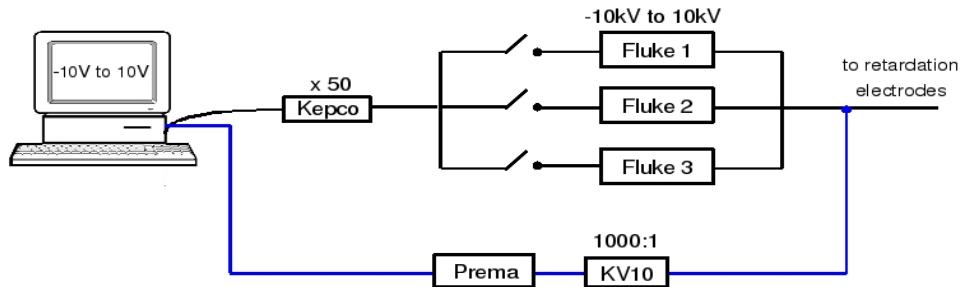
1) Cool, trap and release the ions



3) Only count when the bunch arrives



2) Define a voltage scan region ΔV

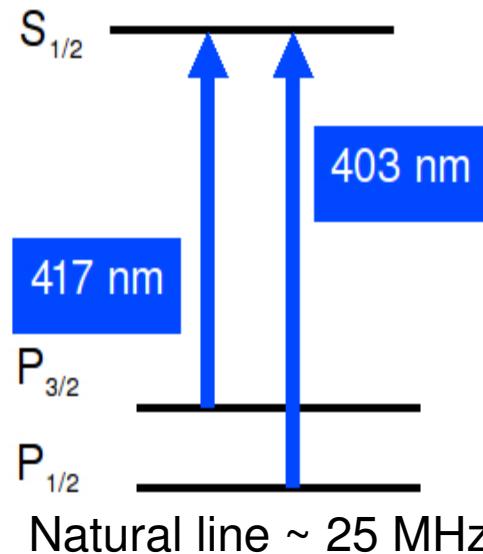


Background reduced by

$$\frac{t_{acc}}{t_{bunch}} \approx \frac{50\text{ ms}}{20\text{ } \mu\text{s}} \approx 2.5 \times 10^3$$

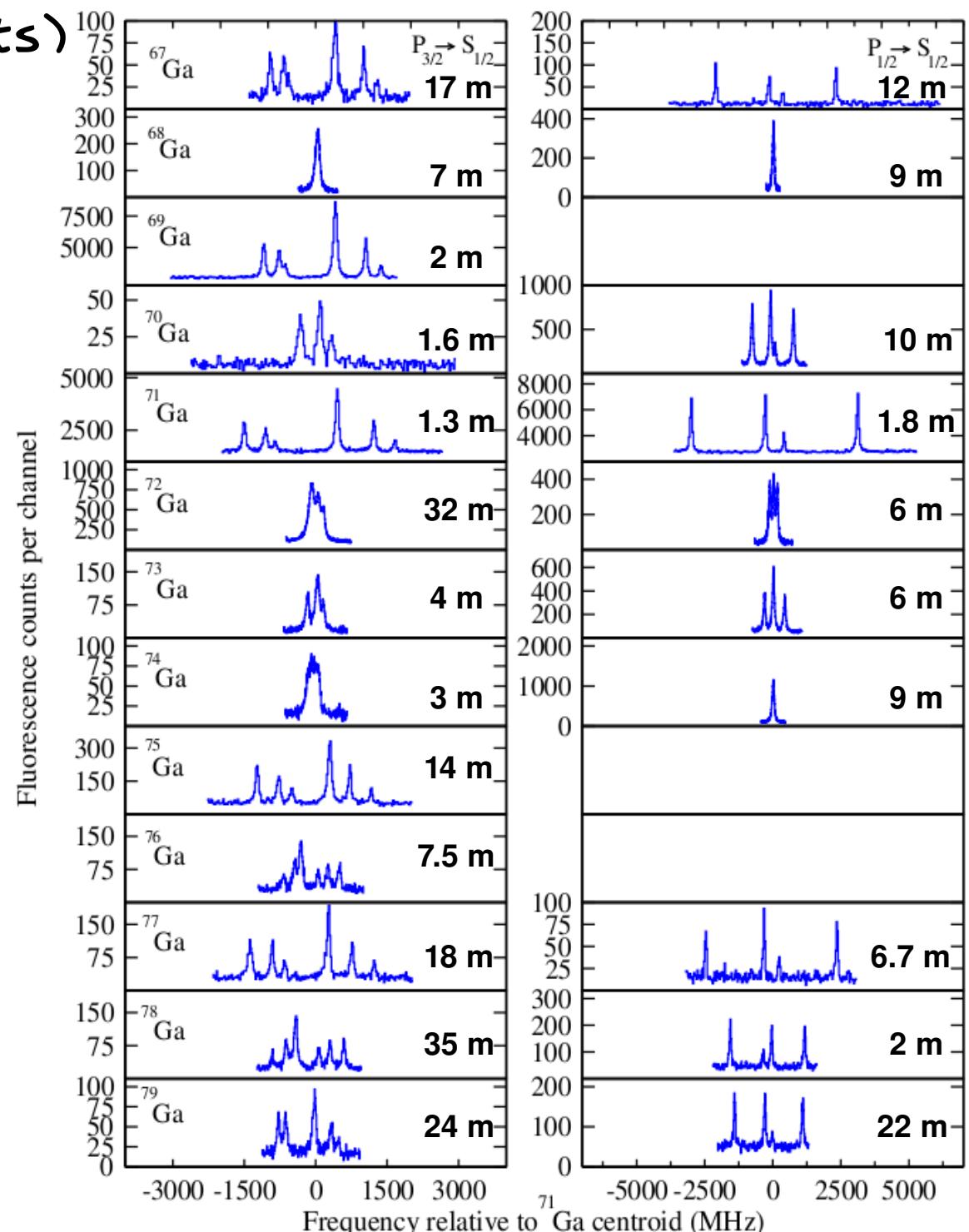
The results (of 5 shifts)

Gallium atomic structure



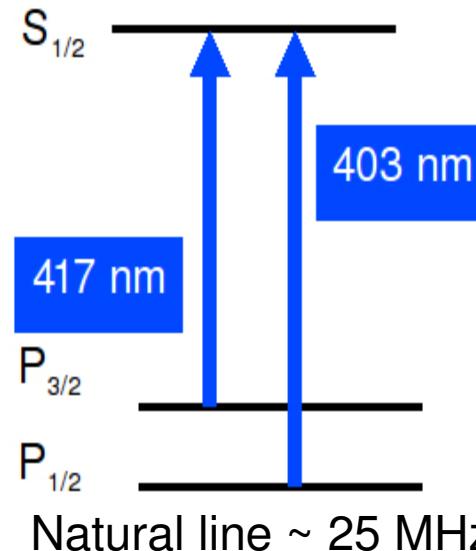
Ga yields (T. Stora)

	UC375 – surface(Nb)	UC375 – RILIS	UC259 – RILIS 2000/2030C [1,2]	UC183 – RILIS (Nb) 2100/2100C [2,3]
73Ga (/ μ C)	-	1.8e9		
74Ga (/ μ C)	3.0e6	9.0e8	3.9e7	2.8e7
75Ga (/ μ C)	-	2.4e8		2.1e7 (on target)
78Ga (/ μ C)	-	5e7 (extrap)		3.9e6
79Ga (/ μ C)	-	3e7 (extrap)		2.6e6
80Ga (/ μ C)	-	5e6 (extrap)		3.5e5
83Ga (/ μ C)	-	1.1-1.7e5		4.5e3 (on converter)



The results-Odds

Gallium atomic structure



Hyperfine structure: $F = I + J$

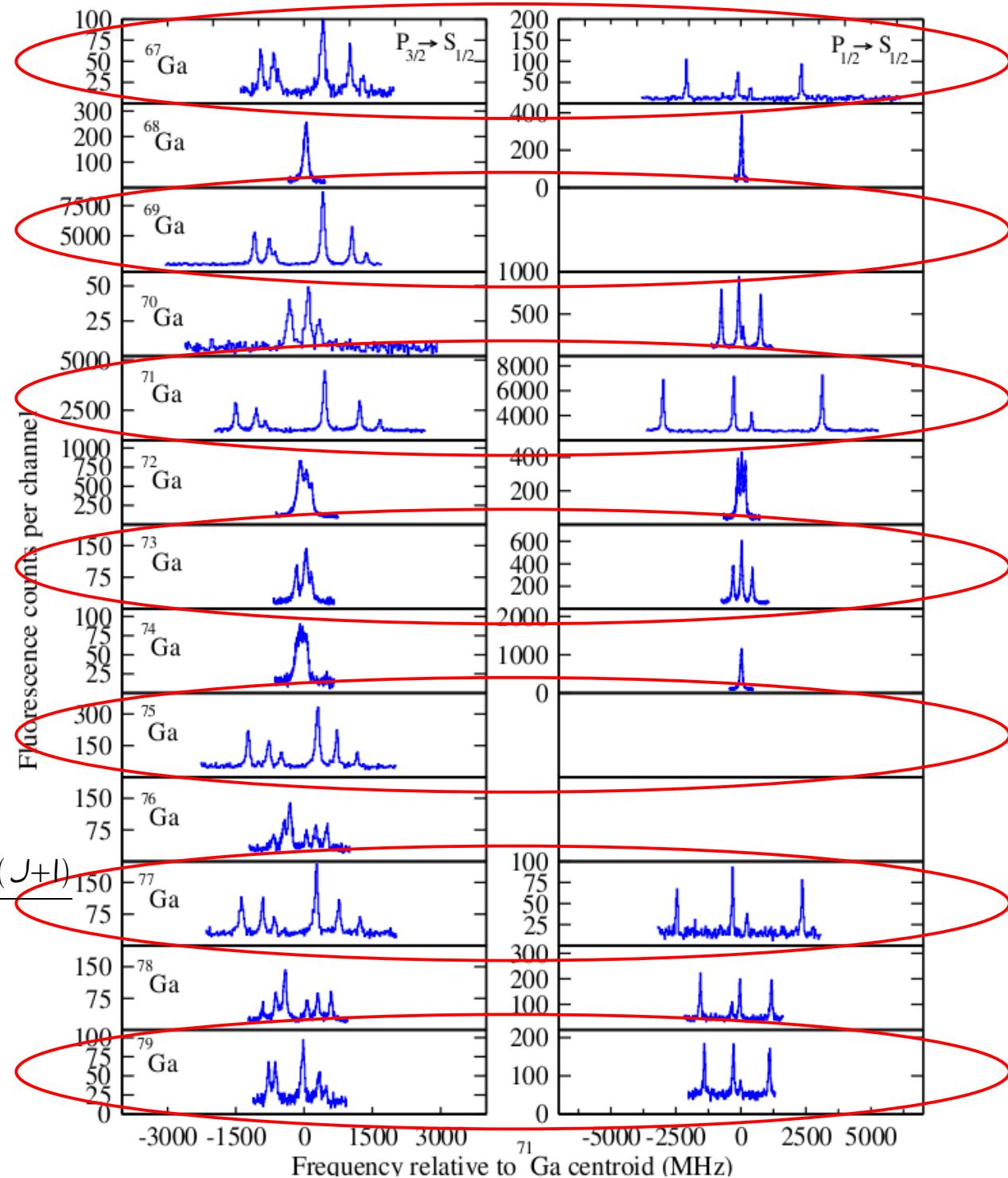
Energy of a hyperfine multiplet:

$$\omega_F = \omega_J + A \frac{C}{2} + B \frac{(3C/4)(C+I) - I(I+I)J(J+I)}{2I(2I+I)J(2J+I)}$$

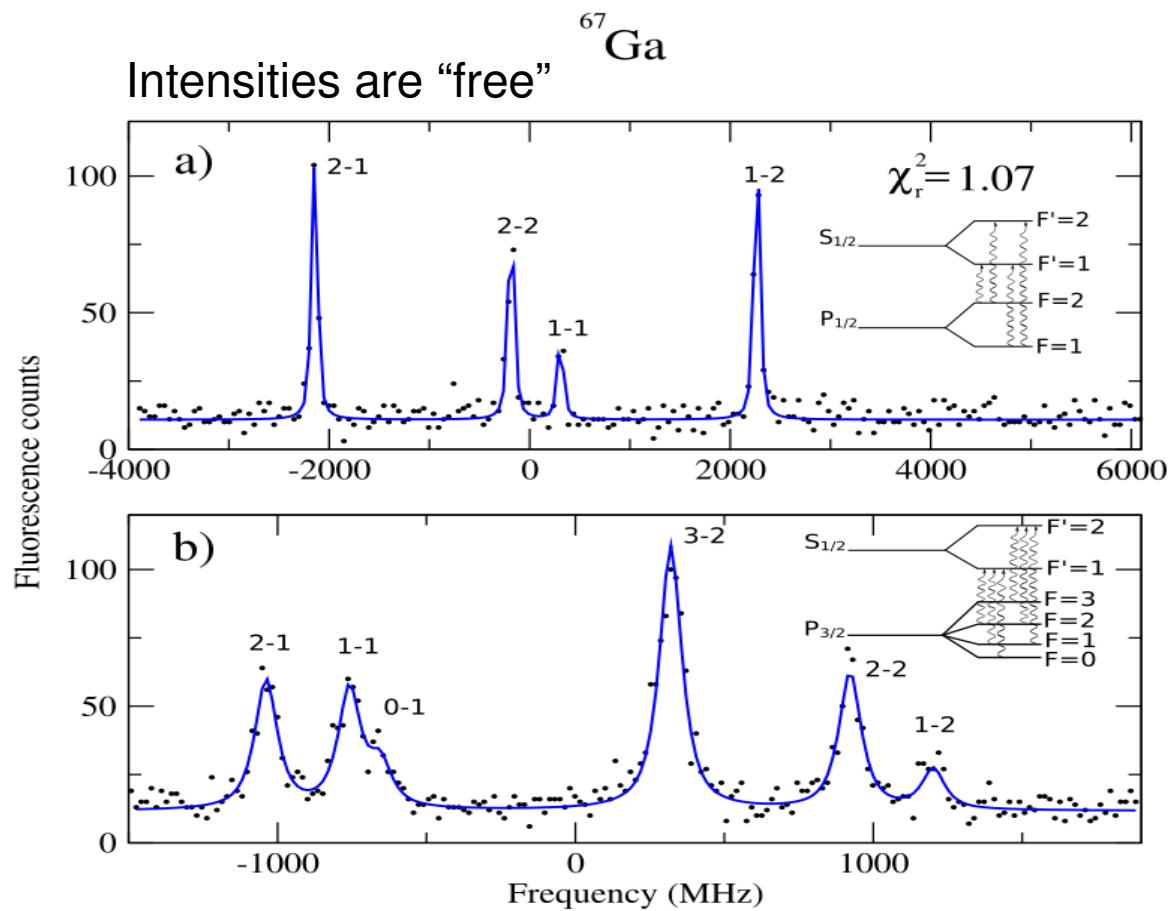
where:

$$A = \frac{\mu_e B_{el}}{IJ} \quad B = eQ_s \left(\frac{\partial^2 V_e}{\partial Z^2} \right)$$

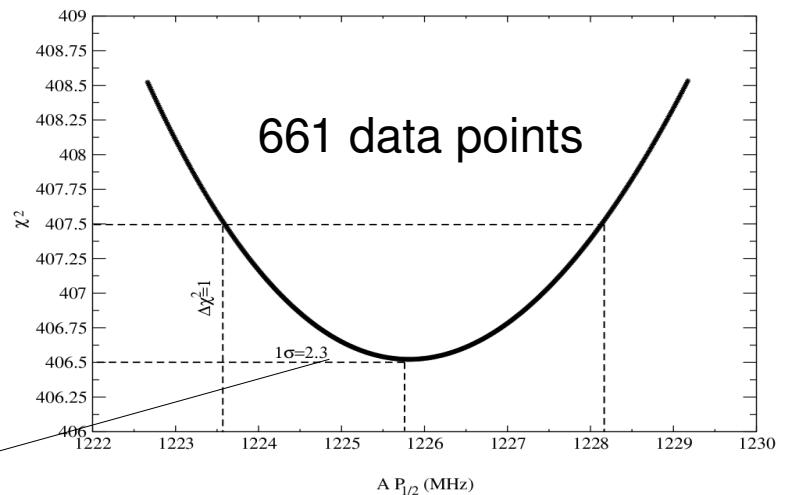
$$C = F(F+1) - I(I+1) - J(J+1)$$



Spectra fitted simultaneously using the ROOT framework



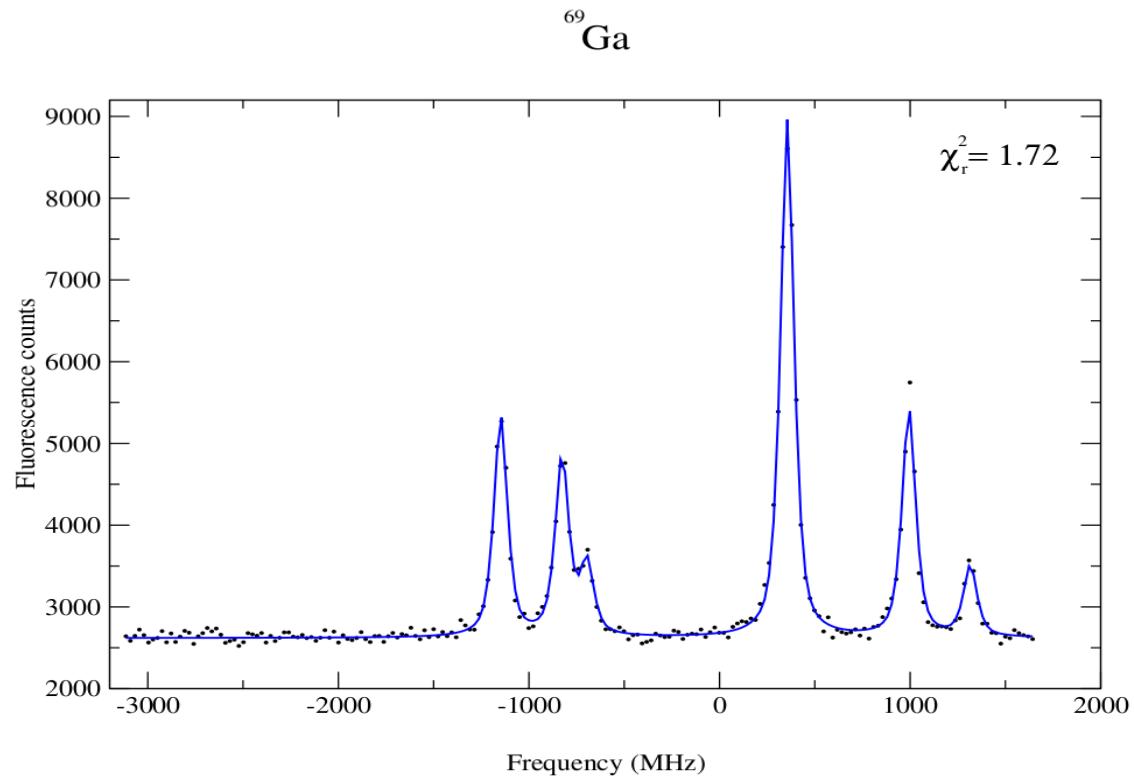
22 free parameters in χ^2 hyperspace



Good agreement with published values

Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{67}Ga	This work	3/2	1225.8(23)	980.3(16)	176.3(11)	73.0(33)
	Ref. [1]	3/2	1228.86582(45)		175.09736(15)	71.95750(55)

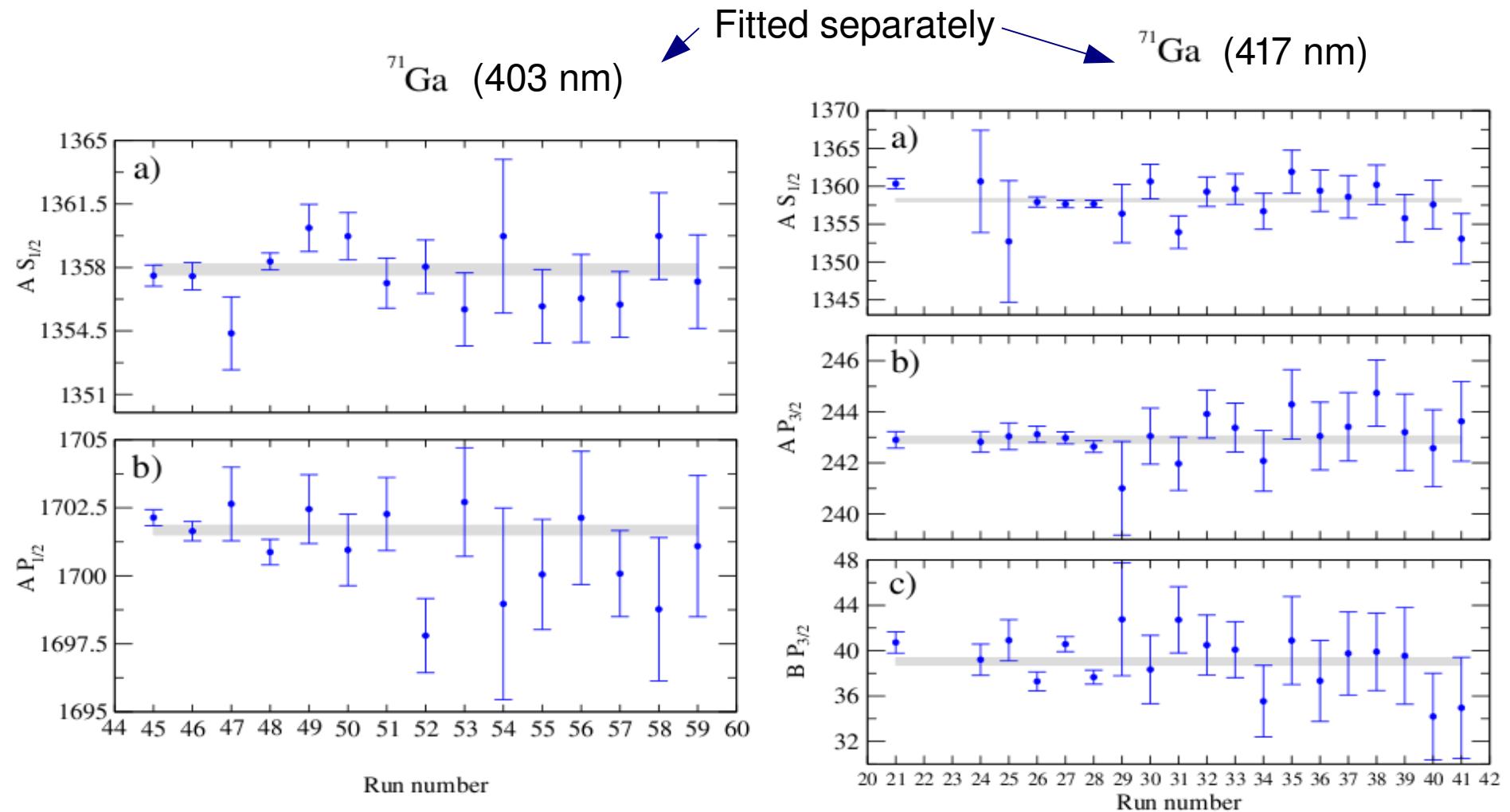
^{69}Ga : good agreement with previous measurement



Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{69}Ga	This work	3/2		1070.9(5)	191.9(2)	61.7(7)
	Ref. [1]	3/2	1339	1069	190.8	62.5
	Ref. [2]	3/2	1339(2)	1075(3)		

- [1] Appl. Phys. B, 77:809–815, 2003.
[2] Physica, 98C:235–241, 1980

^{71}Ga : Our gold standard



Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{71}Ga	This work	3/2	1701.7(2) ^a	1358.04(19) ^b	242.9(1) ^c	39.05(33) ^c
	Ref. [1]	3/2	1701	1358	242.4	39.4
	Ref. [2]	3/2		1364(3)		

^aWeighted average based on 403nm calibration runs

^bWeighted average based on 403nm and 417nm calibration runs

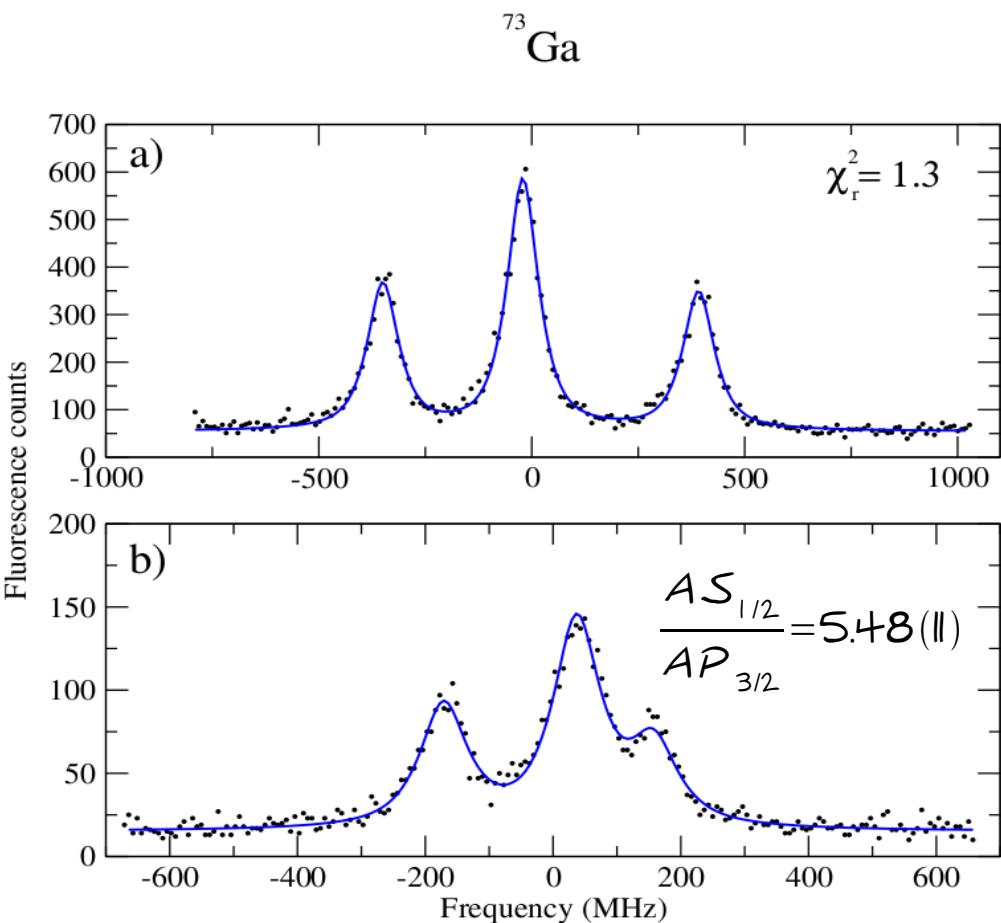
^cWeighted average based on 417nm calibration runs

$$\frac{AS_{1/2}}{AP_{3/2}} = 5.59(2)$$

[1] Appl. Phys. B, 77:809–815, 2003.

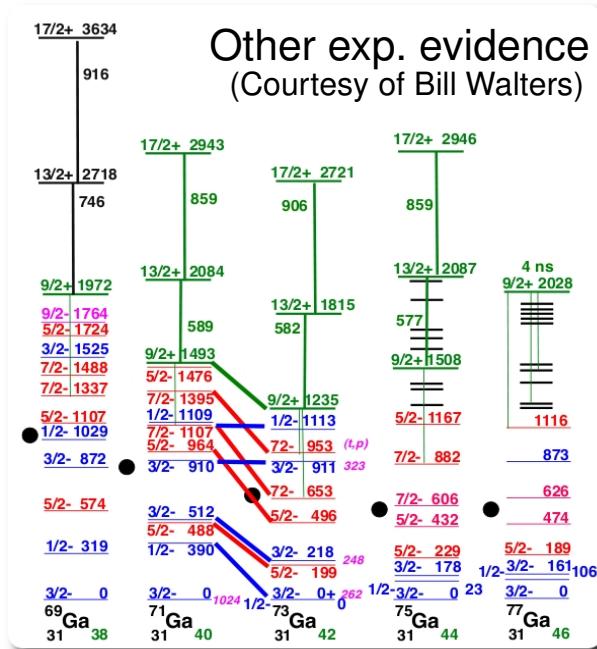
[2] Physica, 98C:235–241, 1980

A "hard" case: ^{73}Ga

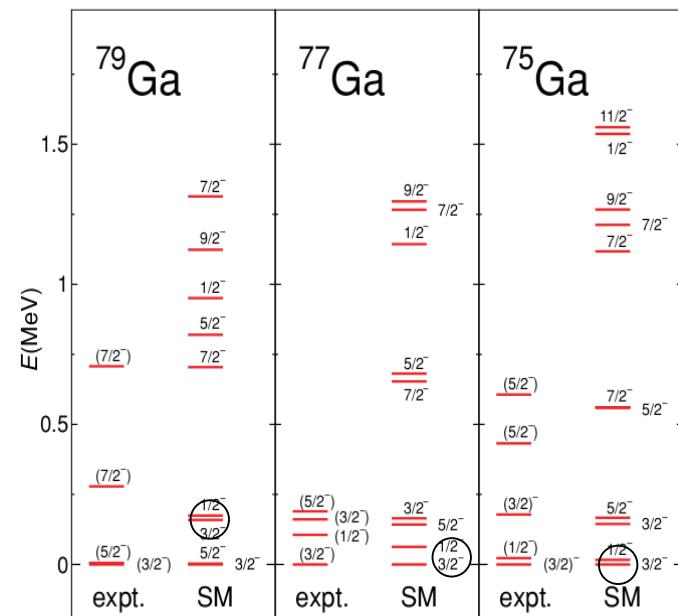


a) measured on the 403 nm transition
 b) measured on the 417 nm transition

Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$
^{73}Ga	This work	$1/2$	412.8(13)	328.6(12)	60.1(12)
	Ref. [1]	$3/2$			

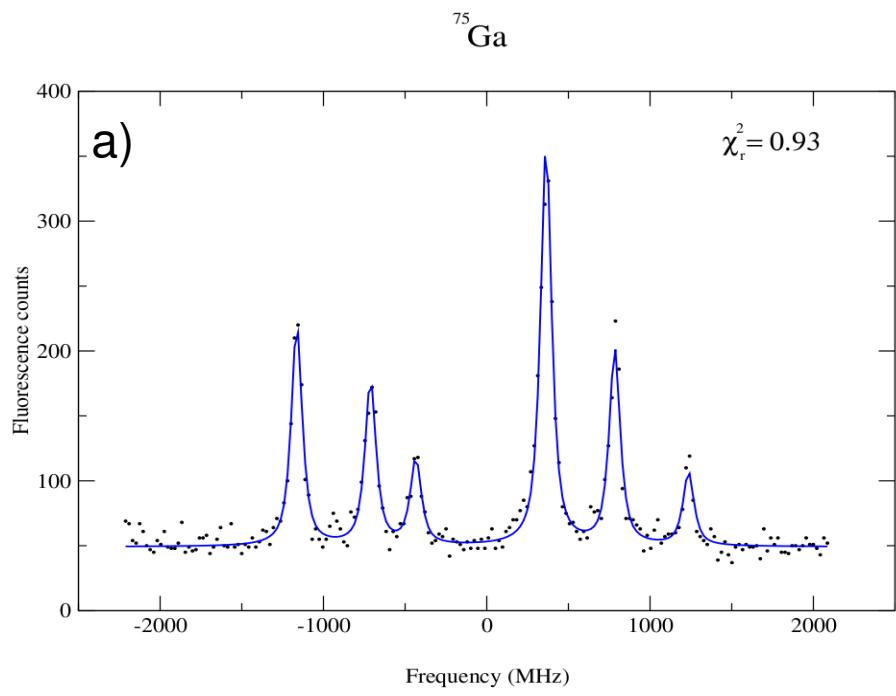


Theory correctly reproduces the $1/2$ level decrease

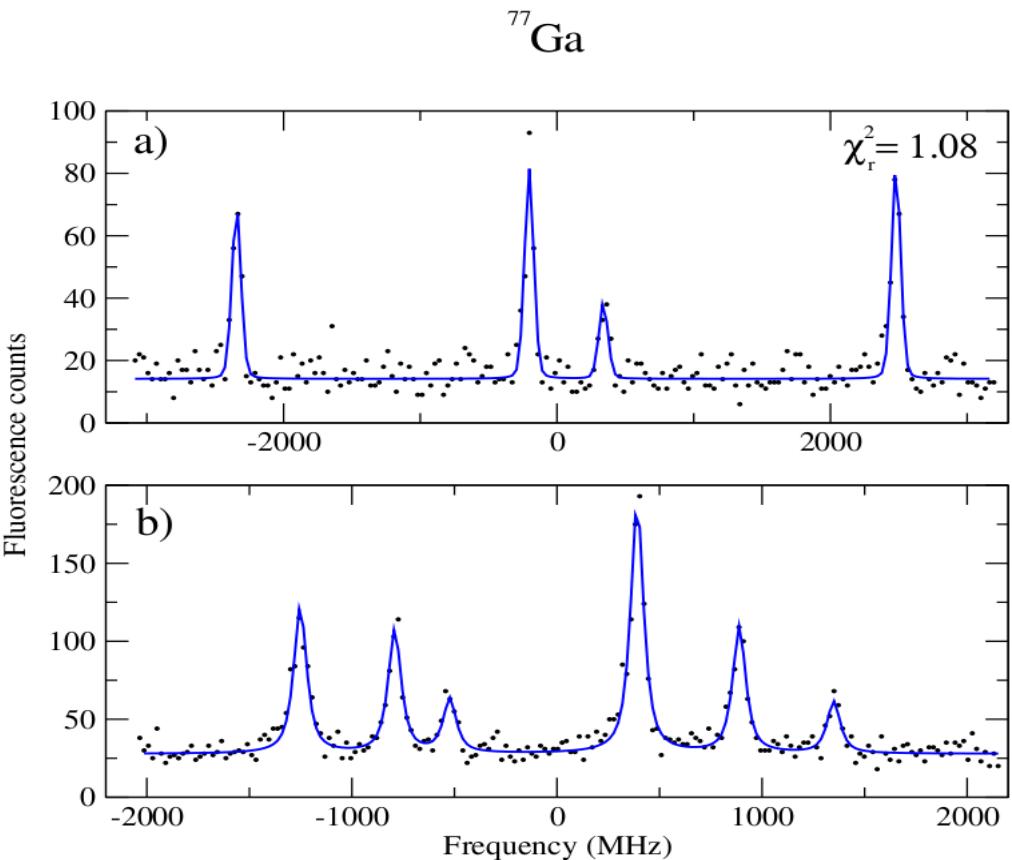


Shell model calculation using $g_{9/2}$, $p_{1/2}$, $p_{3/2}$, and $f_{5/2}$ orbitals PRC 78, 044320 (2008)

$^{75}\text{-}^{77}\text{Ga}$: Change in shape



a) measured on the 403 nm transition
b) measured on the 417 nm transition



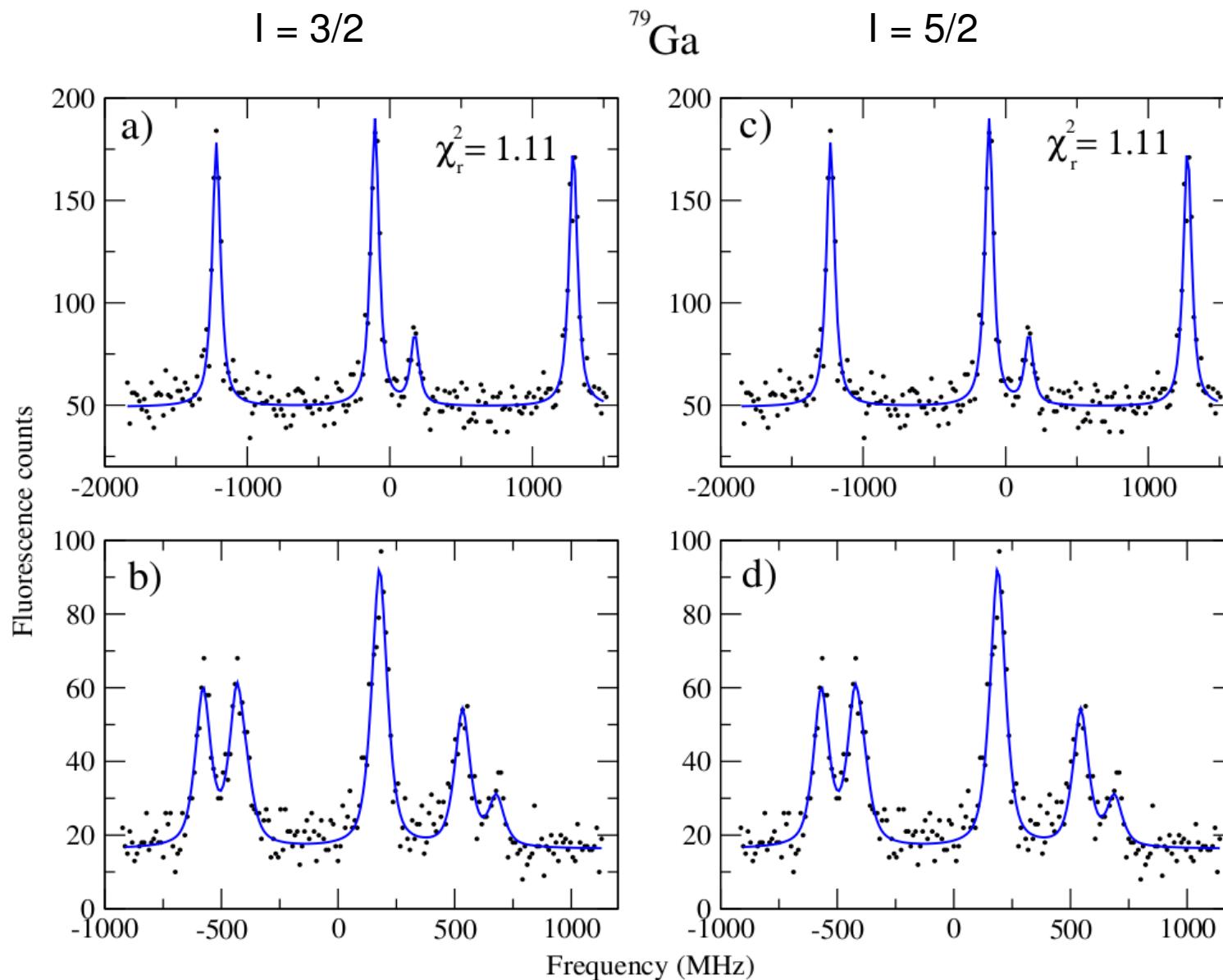
Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{75}Ga	This work	3/2		973.5(13)	174.3(6)	-102.9(18)
	Ref. [1]	(3/2)				
	Ref. [2]	(1/2,3/2)				

Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{77}Ga	This work	3/2	1341.7(22)	1070.5(15)	191.7(7)	-77.1(25)
	Ref. [3]	(3/2)				

- [1] Z. Phys. A, 267 359, 1974.
 [2] PRC, **18**, 86, 1978.
 [3] Physica Scripta, **34** 614, 1986

^{79}Ga : The hardest ($I=3/2$ or $5/2$?)

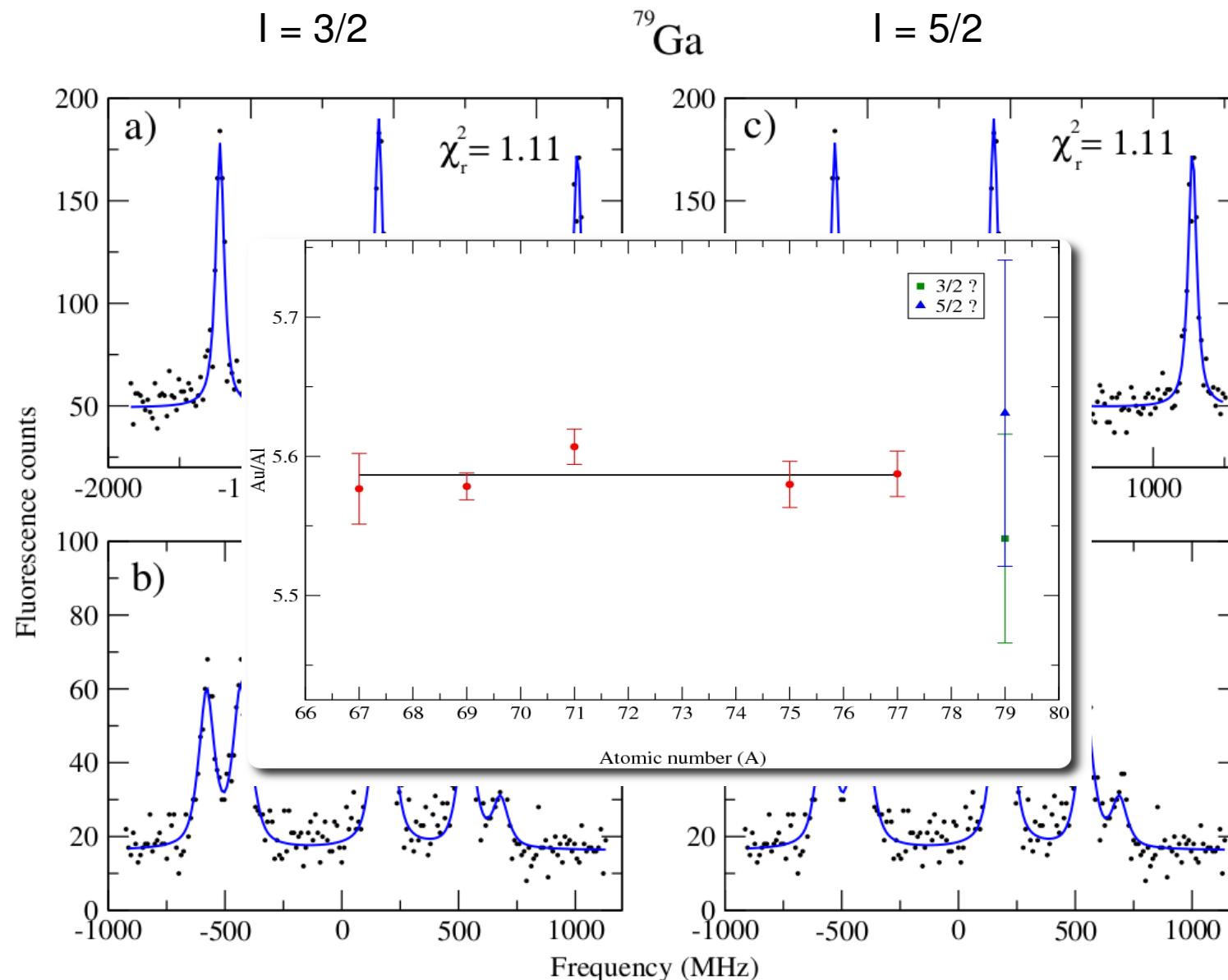
Nuc. Phys. A 368, 210, 1981



$I = 5/2$

- a) measured on the 403 nm transition
- b) measured on the 417 nm transition

^{79}Ga : The hardest ($I=3/2$ or $5/2$?)



- a) measured on the 403 nm transition
- b) measured on the 417 nm transition

^{79}Ga , $I = 3/2$ or $5/2$? One more thing to try:

Look at the relative intensities for the hyperfine peaks. **Ideal case:**

$$S_{F \rightarrow F'} = (2F + 1)(2F' + 1) \begin{Bmatrix} J & F' & I \\ F & J & I \end{Bmatrix}^2, F = I + J$$

But, experimentally things were **not ideal**

403nm

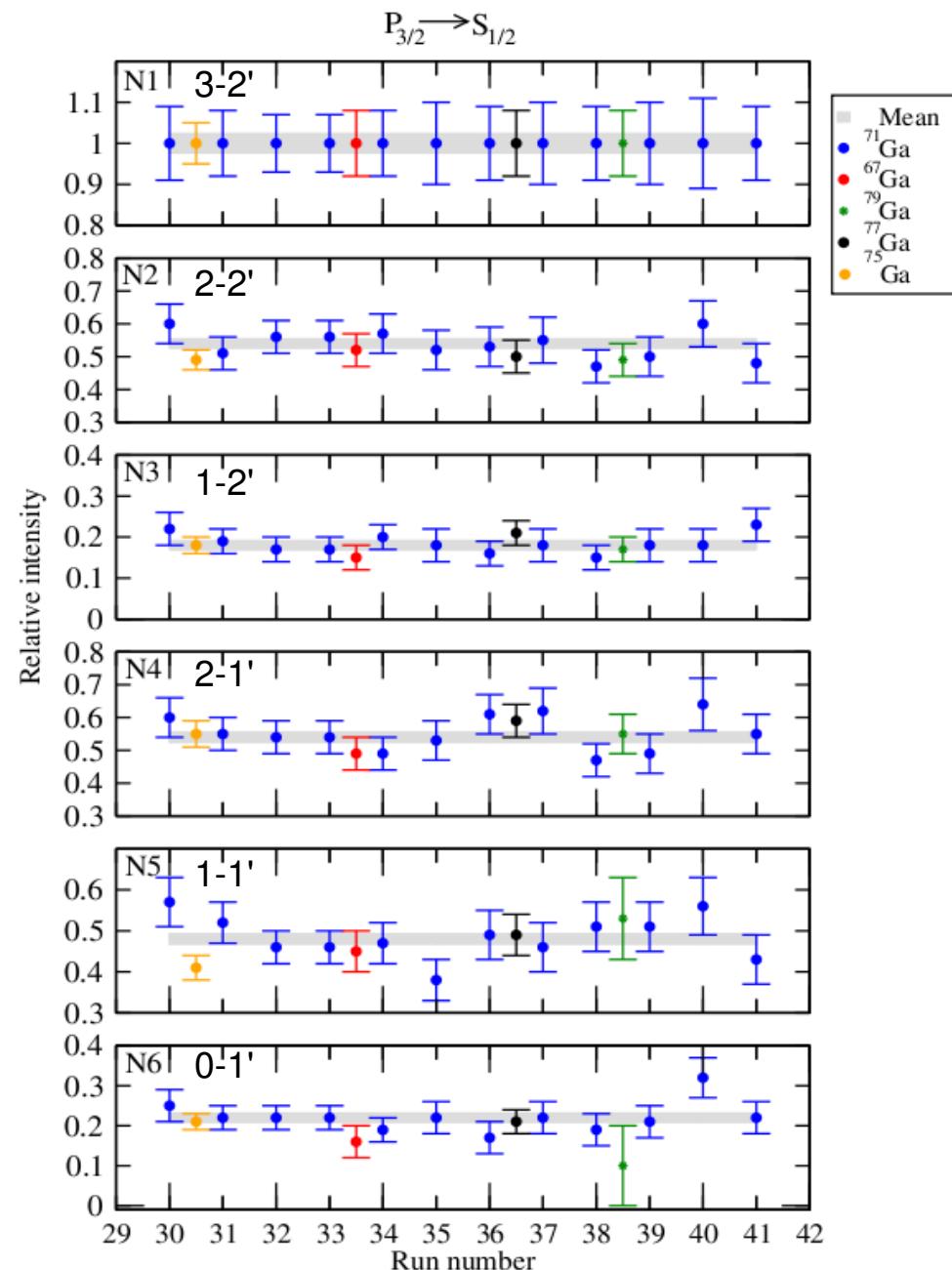
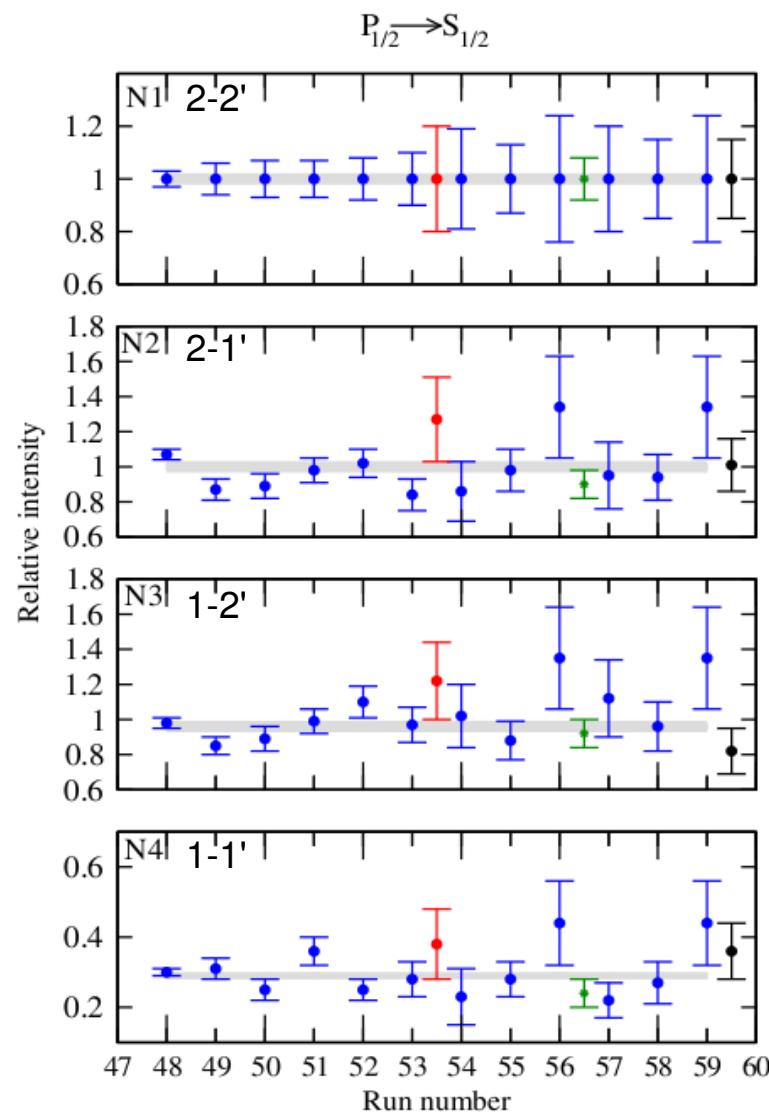
Peak	Racah ($I = 3/2$)	Racah ($I = 5/2$)	^{71}Ga ($I = 3/2$)	^{79}Ga ($I = 3/2, 5/2$)
N1	1 (2-2')	0.8 (3-3')	1.00(2)	1.00(8)
N2	1 (2-1')	1 (3-2')	1.00(2)	0.90(8)
N3	1 (1-2')	1 (2-3')	0.96(2)	0.92(8)
N4	0.2 (1-1')	0.28 (2-2')	0.29(1)	0.24(4)

417 nm

Peak	Racah ($I = 3/2$)	Racah ($I = 5/2$)	^{71}Ga ($I = 3/2$)	^{79}Ga ($I = 3/2, 5/2$)
N1	1 (3-2')	1 (4-3')	1.00(2)	1.00(8)
N2	0.35 (2-2')	0.43 (3-3')	0.54(1)	0.49(5)
N3	0.07 (1-2')	0.12 (2-3')	0.18(1)	0.17(3)
N4	0.35 (2-1')	0.34 (3-2')	0.54(1)	0.55(6)
N5	0.35 (1-1')	0.43 (2-2')	0.48(1)	0.53(1)/0.49(13)
N6	0.14 (0-1')	0.33 (1-2')	0.22(1)	0.1(1)/0.13(13)

Fluctuations in laser power and beam intensity are the main causes

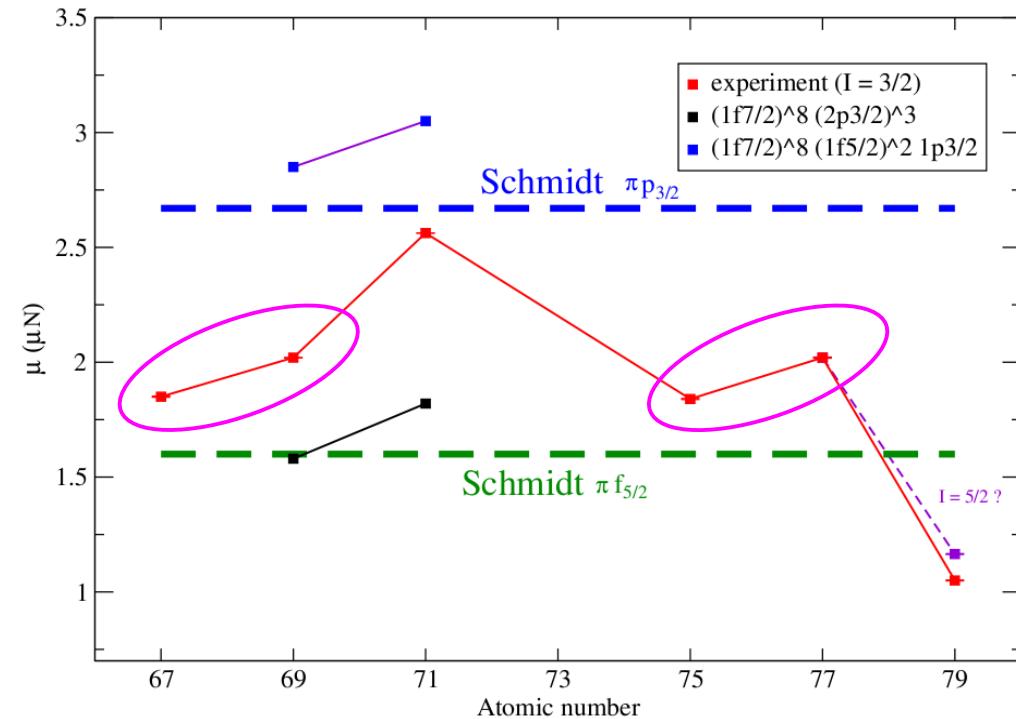
Evolution of the rel. intensity of each $l=3/2$ HF peak in the run



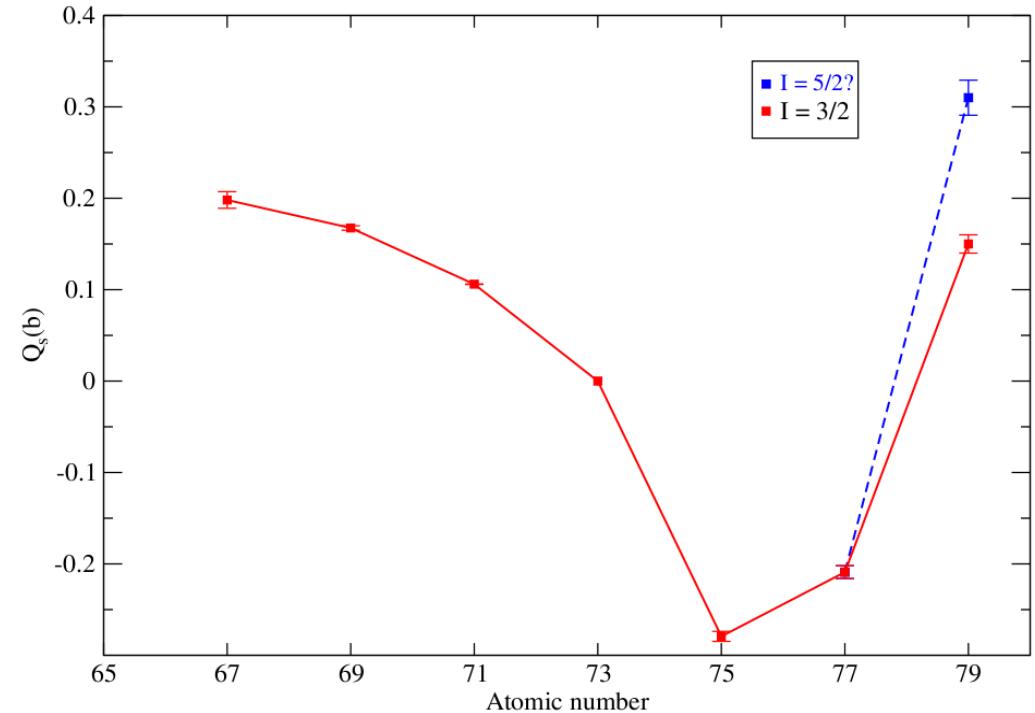
(⁷¹Ga as reference)

Moments

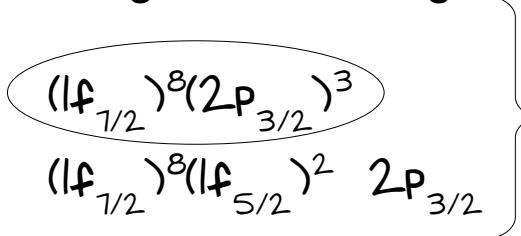
$$\mu = \frac{A/I}{A_{\text{ref}}/I_{\text{ref}}} \mu_{\text{ref}}$$



$$Q_s = \frac{B}{B_{\text{ref}}} Q_{\text{ref}}$$



Configuration mixing



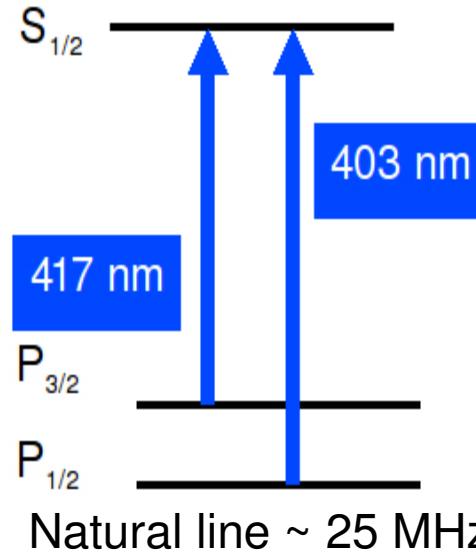
A. Arima and H. Horie . Prog. Theor. Phys. (Japan) 12, n 4(1954)

Maximum of deformation at N=44

The first configuration is favored because Q is +ve...but how about ⁷⁵⁻⁷⁷Ga?

The results-even

Gallium atomic structure



Hyperfine structure: $F = I + J$

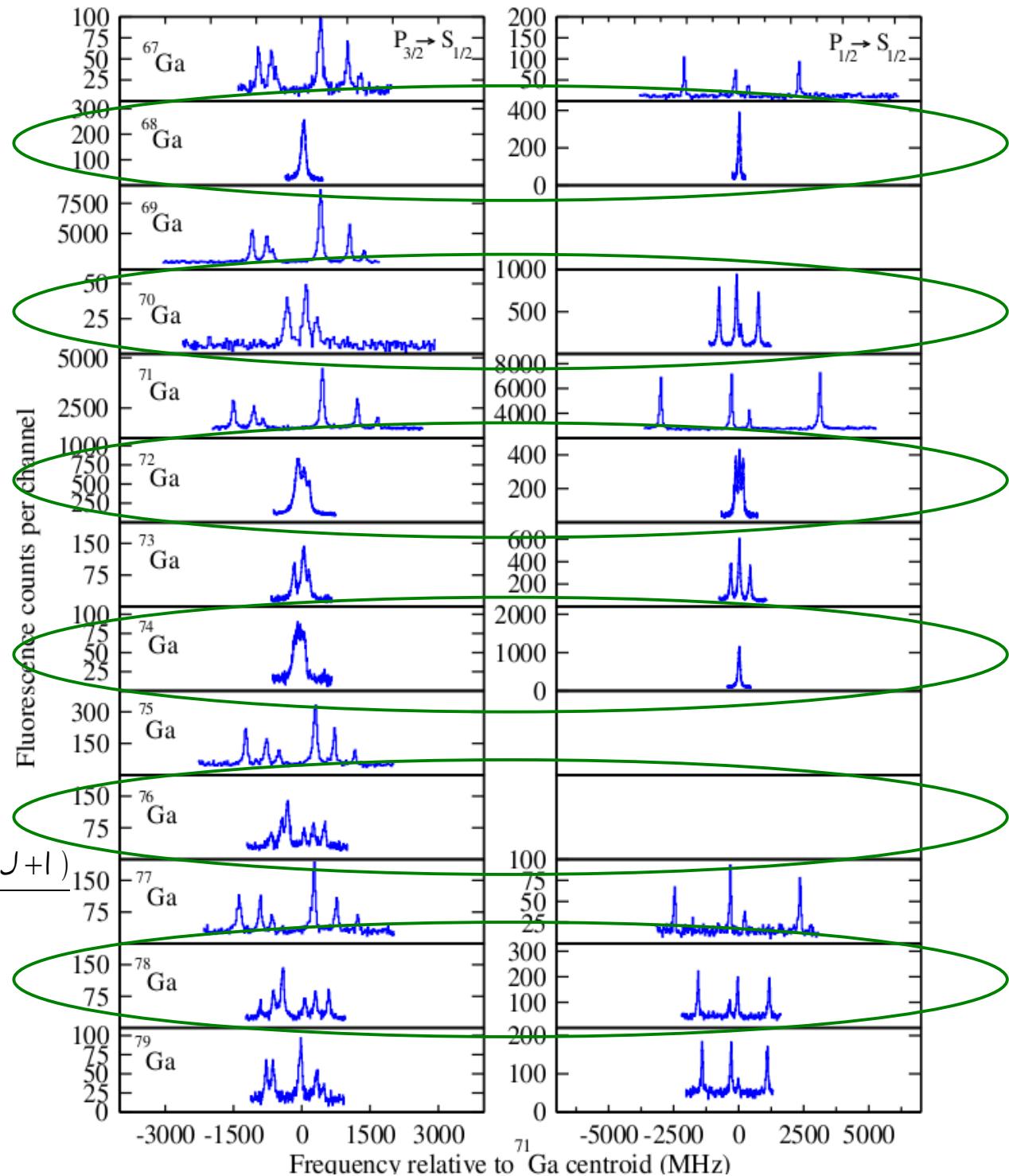
Energy of a hyperfine multiplet:

$$\omega_F = \omega_J + A \frac{C}{2} + B \frac{(3C/4)(C+I) - I(I+1)J(J+1)}{2I(2I+1)J(2J+1)}$$

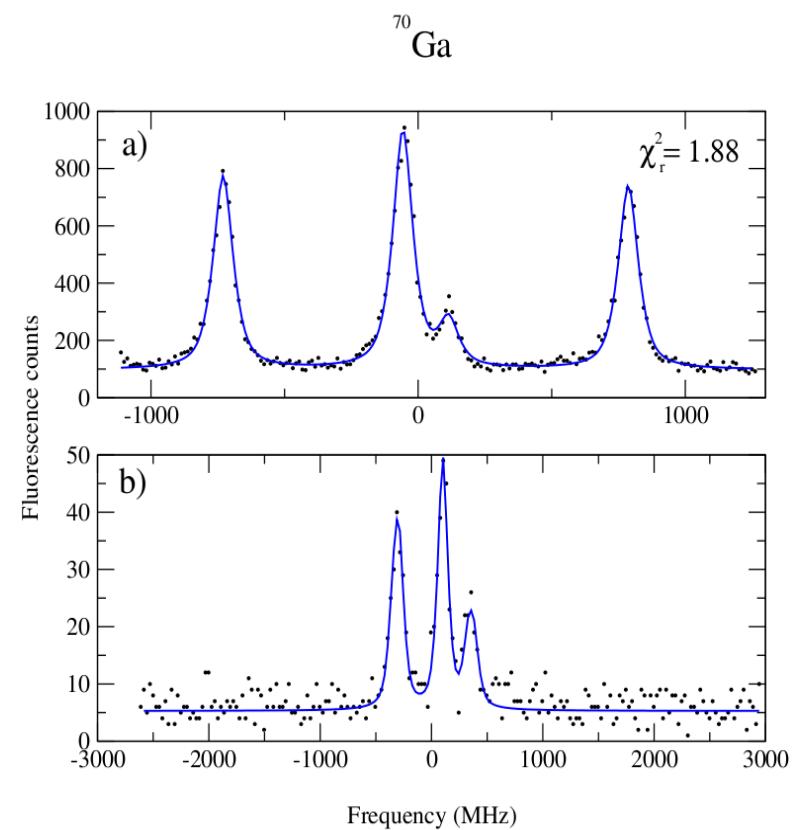
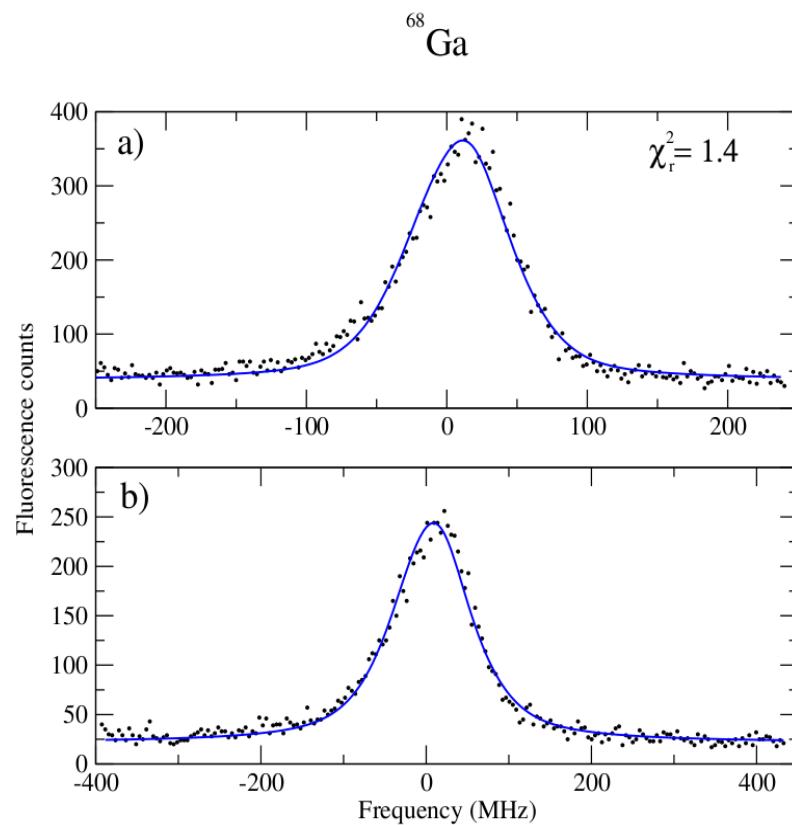
where:

$$A = \frac{\mu_e B_{el}}{IJ} \quad B = eQ_s \left(\frac{\partial^2 V_e}{\partial z^2} \right)$$

$$C = F(F+1) - I(I+1) - J(J+1)$$



$^{68-70}\text{Ga}$



Fixed A $S_{1/2}$, A $P_{1/2}$ and A $P_{3/2}$
(μ and Q_s known) and ratios

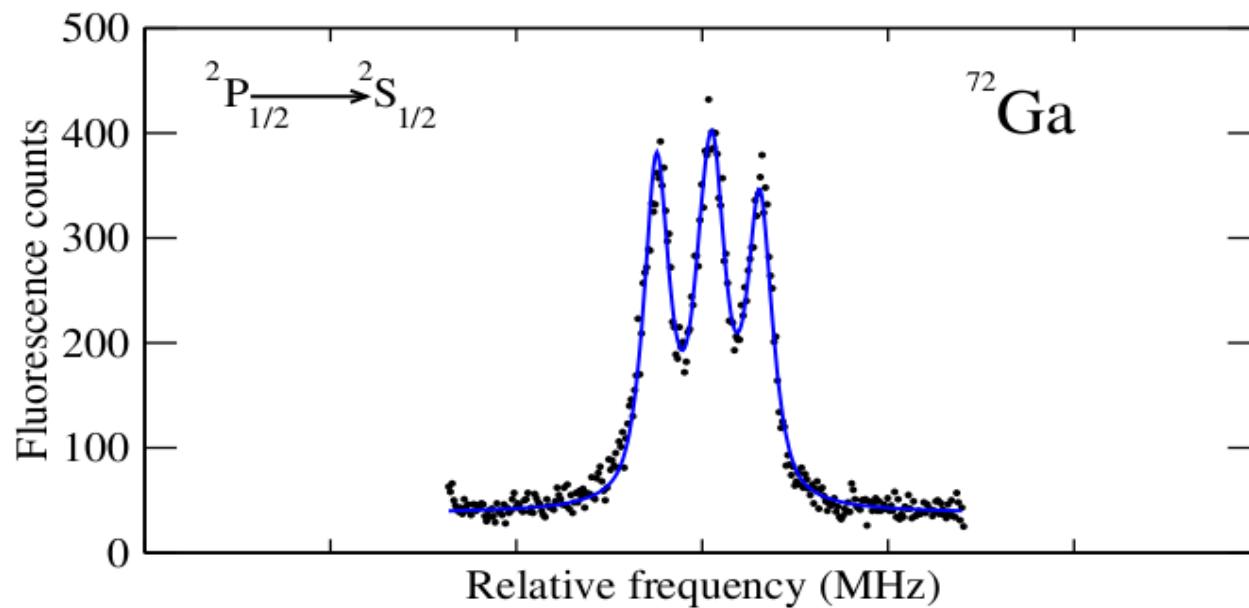
But too small to get the signs!

Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{70}Ga	This work	1	562.5(6)	448.5(6)	76.9(28)	28.9(90)

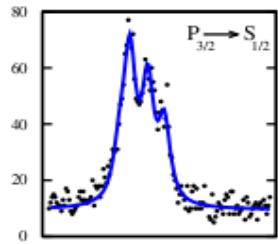
Confirmation of $I=1$

$$\frac{AS_{1/2}}{AP_{3/2}} = 5.83(2)$$

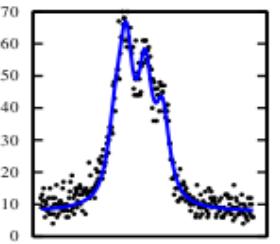
^{72}Ga



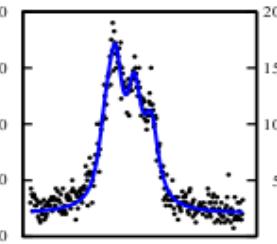
Run #001



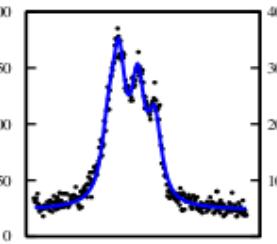
Run #002



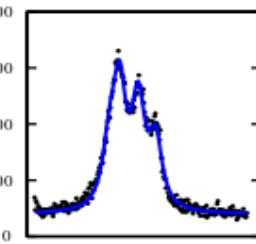
Run #003



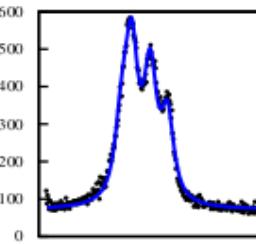
Run #004



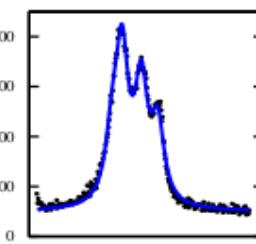
Run #005



Run #006



Run #007



BP_{3/2} (MHz) = 252(20)

248(13)

236(11)

241(7)

243(27)

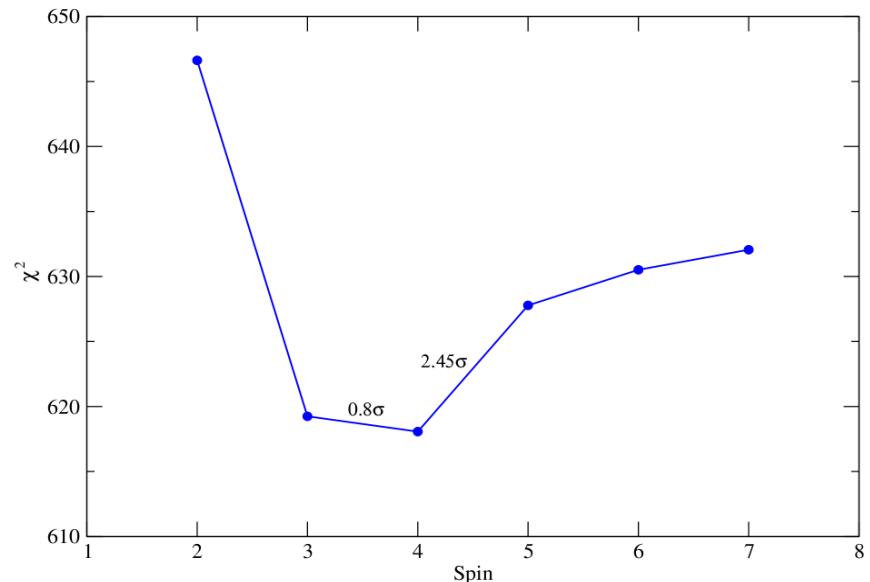
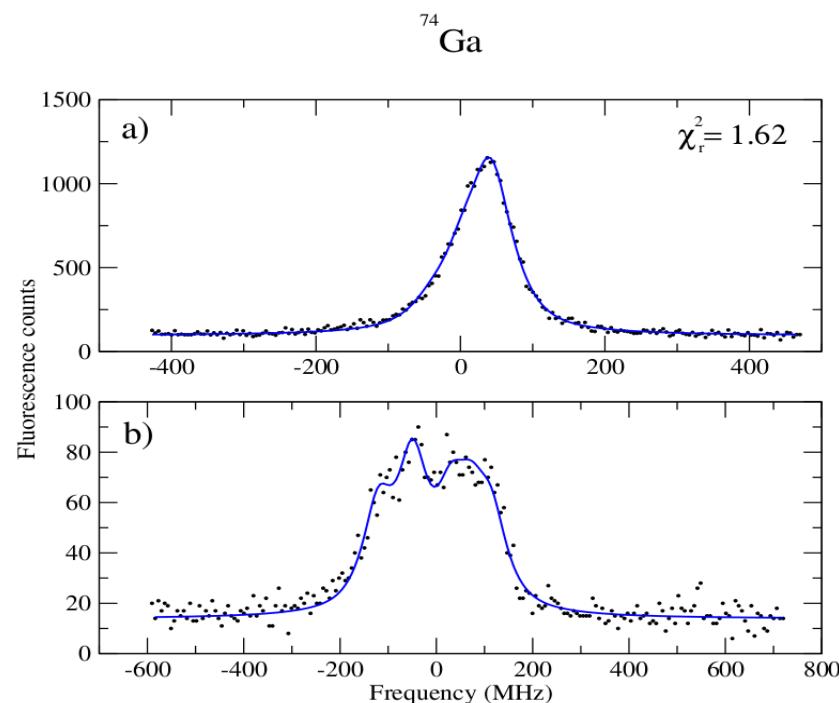
239(4)

235(4)

Isotope	Source	Spin	A _{P_{1/2}}	A _{S_{1/2}}	A _{P_{3/2}}	B _{P_{3/2}}
^{72}Ga	This work	3	-43.7(4)	-35.5(3)	-6.35(5) ^a	235(4)
	Ref. [1]	3	-43.90076(15)	-6.25698(11)	193.67365(80)	

^aThis value was fixed to the ratio of A_{S_{1/2}} to A_{P_{3/2}}

Another "hard" case: ^{74}Ga



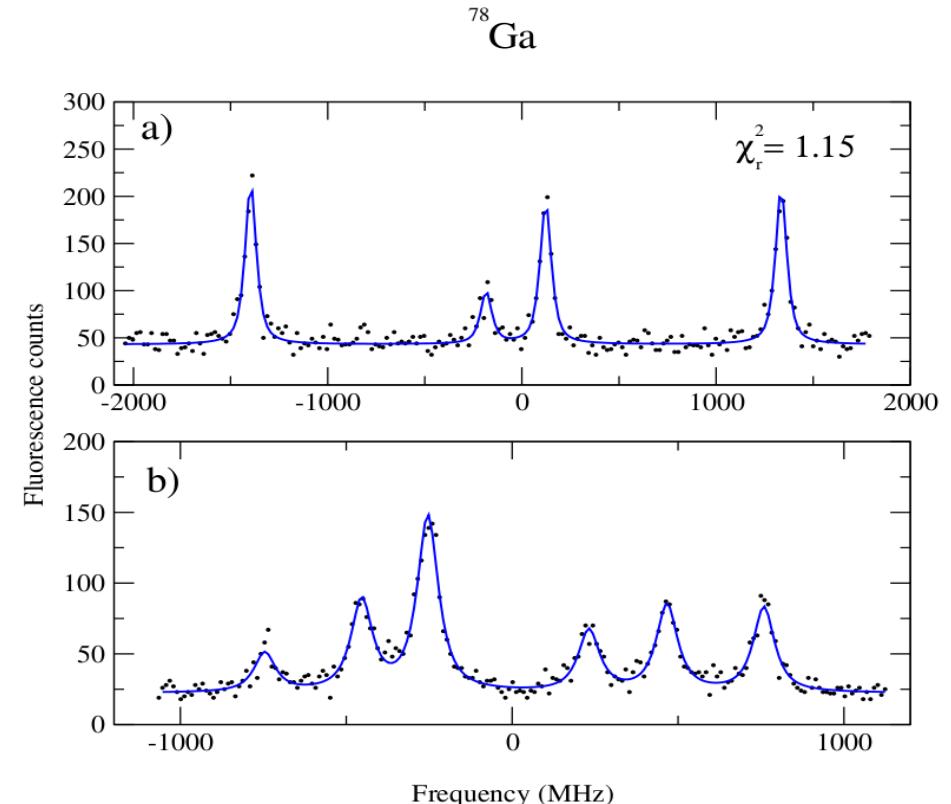
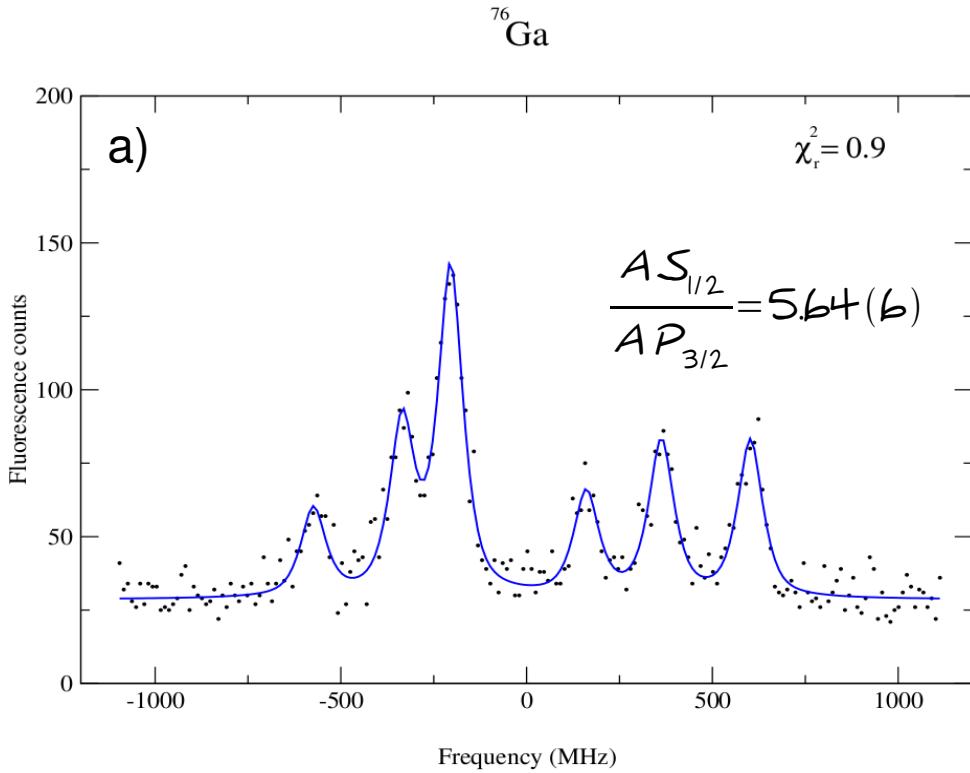
Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{74}Ga	This work	3	10.3(4)	12.9 ^a	1.85 ^a	189.6(86)
	This work	4	8.2(3)	10.3 ^a	1.47 ^a	226.9(73)
	Ref. [1]	(3,4)				
	Ref. [2]	(4,5)				

^aThis value was fixed to the ratio of $A_{S_{1/2}}$ to $A_{P_{1/2}}$ and $A_{S_{1/2}}$ to $A_{P_{3/2}}$

[1] Physica, **25**, 694, 1959

[2] Nuc. Phys. **36**, 425 , 1962

$^{76-78}\text{Ga}$



Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{76}Ga	This work	2		-374.6(15)	-66.4(6)	117.2(29)
	Ref. [1]	(3 ⁻)		[1] Nuc. Phys. A, 177 , 401, 1971		
	Ref. [2]	(2 ⁺)		[2] Physica Scripta, 34 , 614, 1986		

Isotope	Source	Spin	$A_{P_{1/2}}$	$A_{S_{1/2}}$	$A_{P_{3/2}}$	$B_{P_{3/2}}$
^{78}Ga	This work	2	-607.6(9)	-484.9(8)	-86.9(5)	119.7(24)
	Ref. [1,2]	(3)				

[1] Phys. Rev. C, **22**(5), 2178, 1980

[2] Phys. Rev. C, **22**(6), 2547, 1980

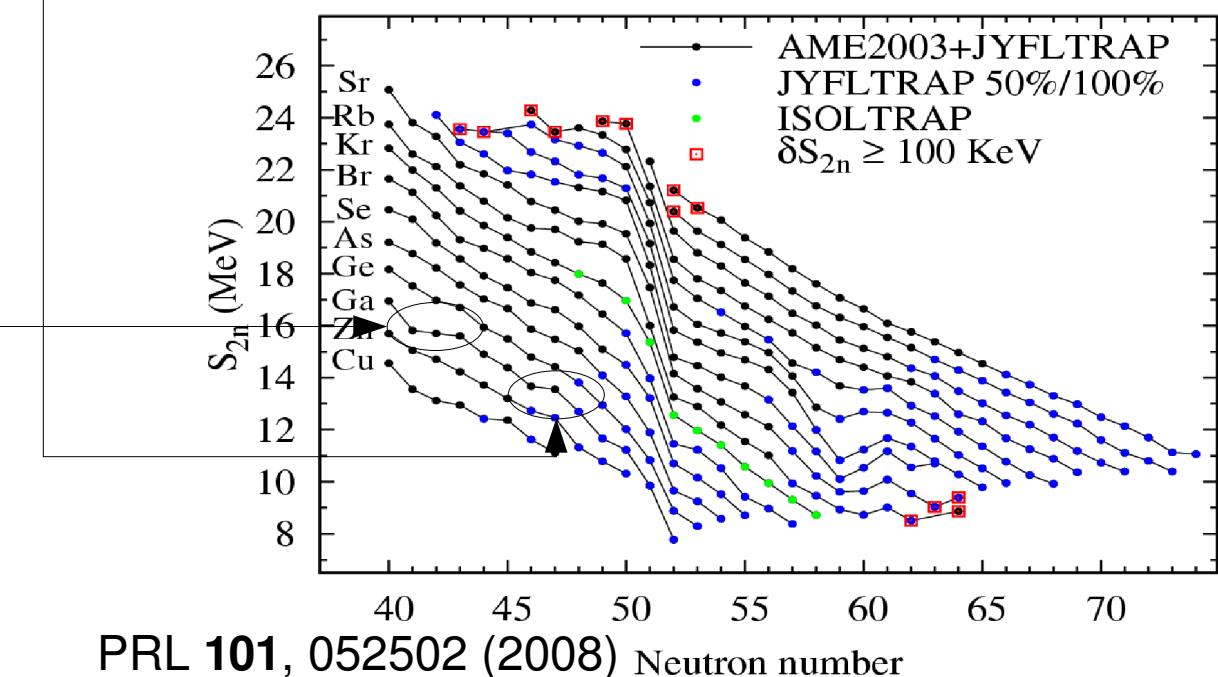


Spin	$A_{S_{1/2}}/A_{P_{3/2}}$	χ^2
2	5.58(3)	437.51
3	5.21(3)	470.67
4	5.08(3)	508.62

Summary of moments

A	I	Previous work (Stone 2005)		This work		
		$\mu(\text{nm})$	$Q_s(\text{b})$	I	$\mu(\text{nm})$	$Q_s(\text{b})$
67	3/2	+1.8507(3)	0.195(5)	3/2	+1.8483(22)	+0.1981(91) (sign confirmed)
68	1	0.01175(5)	0.0277(14)	1	—	—
69	3/2	+2.01659(5)	+0.17(3)	3/2	+2.0211(9)	+0.1675(24)
70	1	—	—	1	+0.5644(4)	+0.078(24)
71	3/2	+2.56227(2)	+0.106(3)	3/2	—	—
72	3	-0.13224(2)	+0.52(1)	3	-0.13396(5)	+0.63(1)
73	3/2	—	—	1/2	+0.2070(50)	—
74	(3)	—	—	4	+0.041349(17)	+0.61(2)
75	3/2	—	—	3/2	+1.8370(23)	-0.2793(55)
76	(2,3)	—	—	2	-0.9410(34)	+0.3181(83)
77	3/2	—	—	3/2	+2.0201(21)	-0.209(7)
78	(3)	—	—	2	-1.22(1)	+0.325(7)
79	3/2	—	—	3/2	+1.0485(16)	+0.15(1)

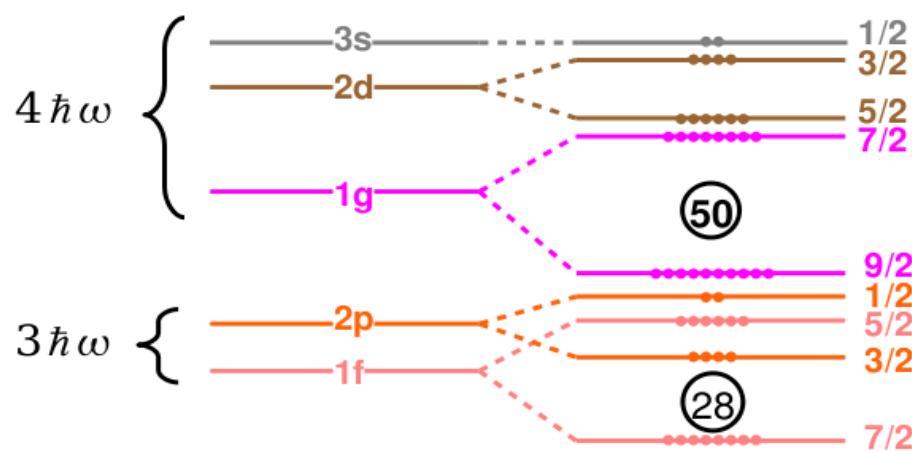
“All” in good agreement



Improving the understanding of this region,
but some puzzles still remain unsolved

Change in parity for Ge and Ga at N=40

	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
33	As 67 43.5 s 5/2- EC, β^+	As 68 151.6 s 3+ EC, β^+	As 69 15.2 m 5/2- EC, β^+	As 70 52.6 m 4(+) EC, β^+	As 71 65.2 h 1/2- EC, β^+	As 72 26 h 2- EC, β^+	As 73 80.3 d 3/2- EC	As 74 17.7 d 2- β^- , EC, β^+	As 75 3/2-	As 76 1.07d 2- β^-	As 77 38.8 h 3/2- β^-	As 78 90.7 m 2- β^-	As 79 9 m 3/2- β^-	As 80 15.2 s 1+ β^-	As 81 33.3 s 3/2- β^-	
32	Ge 67 18.9 m 1/2- EC, β^+	Ge 68 270.8 d 0+ EC	Ge 69 39.05 h 5/2- EC, β^+	Ge 70 stable 0+	Ge 71 11.4 d 1/2- EC	Ge 72 0+	Ge 73 9/2+	Ge 74 0+	Ge 75 82.8 m 3/2- β^-	Ge 76 0+	Ge 77 11.3 h 7/2+ β^-	Ge 78 88 m 0+ β^-	Ge 79 18.9 s (1/2-) β^-			
31		Ga 67 3.26 d 3/2- E	Ga 68 67.2 m 1+ E	Ga 69 3/2- E	Ga 70 21.1 m 1+ β^-, E	Ga 71 3/2- E	Ga 72 14.1 h 3- β^-	Ga 73 4.8 h 1/2- β^-	Ga 74 8.1 m (4-) β^-	Ga 75 126 s 3/2- β^-	Ga 76 32.6 s 2(+) β^-	Ga 77 13.2 s 3/2- β^-	Ga 78 5.1 s 2(+) β^-	Ga 79 2.8 s (3/2-) β^-n		
30	Zn 67 5/2- E	Zn 68 0+ E	Zn 69 56.4 m 1/2- β^-	Zn 70 5E13 y 0+ β^-	Zn 71 2.4 m 1/2- β^-	Zn 72 46.5 h 0+ β^-	Zn 73 23.5 s (1/2-) β^-	Zn 74 95.6 s 0+ β^-	Zn 75 10.2 s (7/2+) β^-	Zn 76 5.7 s 0+ β^-	Zn 77 2.1 s (7/2+) β^-	Zn 78 1.4 s 0+ β^-	Zn 79 995 ms (9/2+) β^-n			
29		Cu 67 61.8 h 3/2- β^-	Cu 68 31.1 s 1+ β^-	Cu 69 2.8 m 3/2- β^-	Cu 70 4.5 s 1+ β^-	Cu 71 19.5 s 3/2- β^-	Cu 72 16.6 s 2- β^-	Cu 73 3.9 s 3/2- β^-	Cu 74 1.3 s 3(+) β^-	Cu 75 1.2 s 5/2- β^-	Cu 76 0.64 s 5/2- β^-	Cu 77 469 ms (5/2-) β^-				
	ν $2p_{3/2}$ $1f_{5/2}$ and $2p_{1/2}$								$\nu g_{9/2}$ orbital gets filled							



- Increase in deformation for $^{72,74}\text{Ga}$
- Change of sign of Q between $^{74-75}\text{Ga}$ and $^{76-77}\text{Ga}$
- Drop in deformation between $^{78-79}\text{Ga}$

Next things to be done

- Isotope shifts and systematic errors
- Simulate spectra to understand optical pumping issues ($^{72,74,79}\text{Ga}$)
- Off-line tests in December in order to further investigate the ion bunches



For the future (> 2009):

- There are 8 shifts available to continue the n-rich program
- A proposal for the neutron deficient Ga will be submitted

Theoretical support is needed to understand the features presented

The people involved in this experiment:

Mr. ERNESTO, Mane (University of Manchester)

Dr. AVGOULEA, Malamatenia (Katholieke Universiteit Leuven)

Dr. GEPPERT, Christopher (University of Mainz)

Dr. JOKINEN, Ari (University of Jyvaskyla)

Prof. NEUGART, Rainer (University of Mainz)

Prof. NEYENS, Gerda (Katholieke Universiteit Leuven)

Dr. NORTERSHAUSER, Wilfried (University of Mainz)

Prof. STROKE, Henry (New York University)

Dr. TUNGATE, Garry (University of Birmingham)

Mr. VINGERHOETS, Pieter (Katholieke Universiteit Leuven)

Dr. YORDANOV, Deyan (University of Heidelberg)

Prof. BILLOWES, Jonathan (University of Manchester)

Dr. BISSELL, Mark (Katholieke Universiteit Leuven)

Prof. BLAUM, Klaus (University of Heidelberg)

Dr. CAMPBELL, Paul (University of Manchester)

Ms. CHARLWOOD, Frances (University of Manchester)

Dr. CHEAL, Bradley (University of Manchester)

Dr. FLANAGAN, Kieran (IPN)

Dr. FOREST, David (University of Birmingham)

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Thanks for listening!!

Summary of hyperfine coefficients and spins

A	I	$A_{P_{1/2}}$ (MHz)	$A_{S_{1/2}}$ (MHz)	$A_{P_{3/2}}$ (MHz)	$B_{P_{3/2}}$ (MHz)	$\delta v_{P_{1/2} \rightarrow S_{1/2}}$ (MHz)	$\delta v_{P_{3/2} \rightarrow S_{1/2}}$ (MHz)
67	3/2	1225.8(23)	980.3(16)	176.3(11)	73.0(33)		
68	1	11.6	9.3	1.7	10.8		
69	3/2	—	1070.9(5)	191.9(2)	61.7(7)		
70	1	562.5(6)	448.5(6)	76.9(28)	28.9(90)		
71	3/2	1701.7(2)	1358.04(19)	242.9(1)	39.05(33)		
72	3	-43.7(4)	-35.5(3)	-6.35	235(4)		
73	1/2	412.8(13)	328.6(12)	60.1(12)	—		
74	4	8.2(3)	10.3	1.47	226.9(73)		
75	3/2	—	973.5(13)	174.3(6)	-102.9(18)		
76	2	—	-374.6(15)	-66.4(6)	117.2(29)		
77	3/2	1341.7(22)	1070.5(15)	191.7(7)	-77.1(25)		
78	2	-607.6(9)	-484.9(8)	-86.9(5)	119.7(24)		
79	3/2	695.8(15)	556.1(12)	100.1(12)	55.3(42)		



Published values

A	A(P1/2)	A(S1/2)	A(P3/2)	B(P3/2)	IS(A - 69)	Ref
67	1228.86582(45)		175.09736(15)	71.95750(55)		Phys Rev 1 176 (1968)
69	1339	1069	190.8	62.5		Appl. Phys. B 77, 809–815 (2003)
	1339(2)	1075(3)				Physica 98C (1980) 235-241
71	17001	1358	242.4	39.4		Appl. Phys. B 77, 809–815 (2003)
		1364(3)		-39.6(3.5)		Physica 98C (1980) 235-241
72	-43.90076(15)		-6.25698(11)	193.67365(80)		Phys Rev 1 176 (1968)

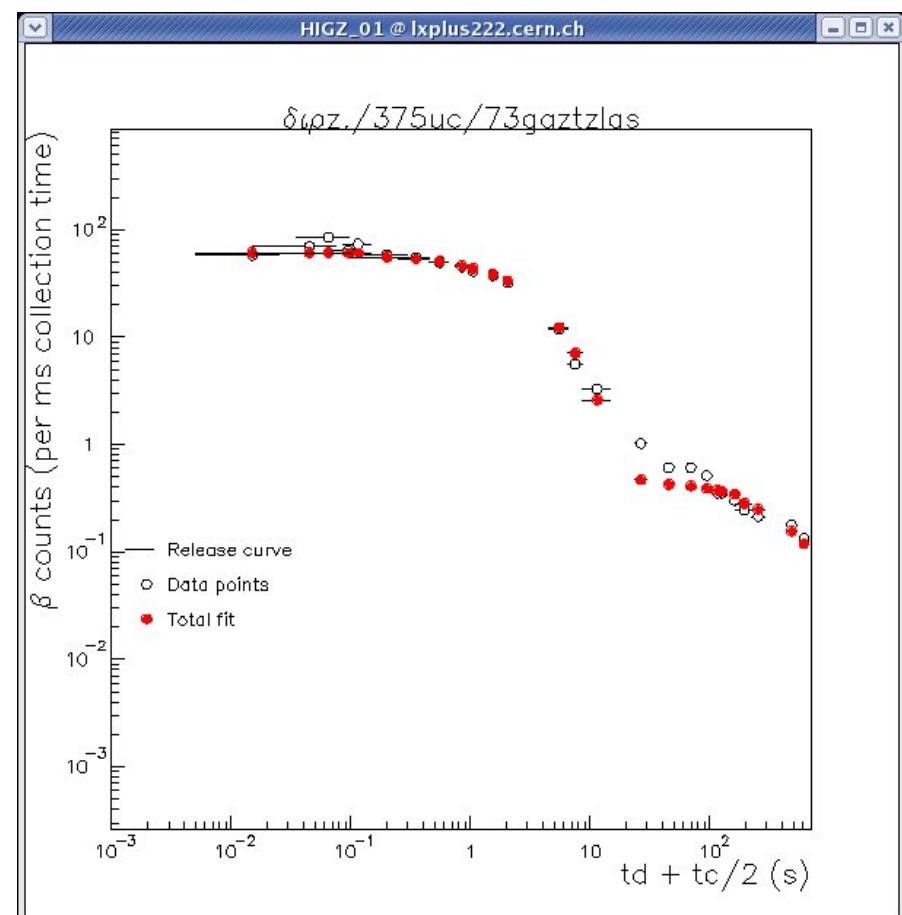
Ga yields (Thierry Stora)

	UC375 – surface(Nb)	UC375 – RILIS	UC259 – RILIS 2000/2030C [1,2]	UC183 – RILIS (Nb) 2100/2100C [2,3]
73Ga (μ C)	-	1.8e9		
74Ga (μ C)	3.0e6	9.0e8	3.9e7	2.8e7
75Ga (μ C)	-	2.4e8		2.1e7 (on target)
78Ga (μ C)	-	5e7 (extrap)		3.9e6
79Ga (μ C)	-	3e7 (extrap)		2.6e6
80Ga (μ C)	-	5e6 (extrap)		3.5e5
83Ga (μ C)	-	1.1-1.7e5		4.5e3 (on converter)

[1] U. Koester, et al.; AIP Conf. Proc. 798 (2005) 315.

[2] <http://www.cern.ch/isolde>, 2008.

[3] U. Koester; Eur. Phys. J. A 15 (2002) 255.



Problem with optical pumping (< 0.4 mW)

Spectra fitted with fixed relative intensities
 ^{71}Ga ($I=3/2$), not bunching

