Lifetime measurements in Zn, Ga and Ge isotopes around N=40

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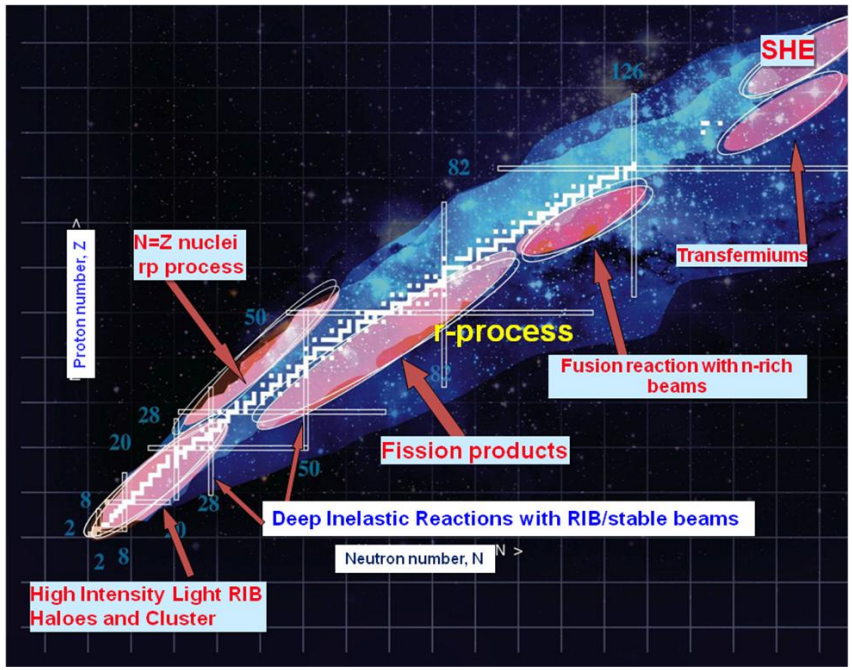
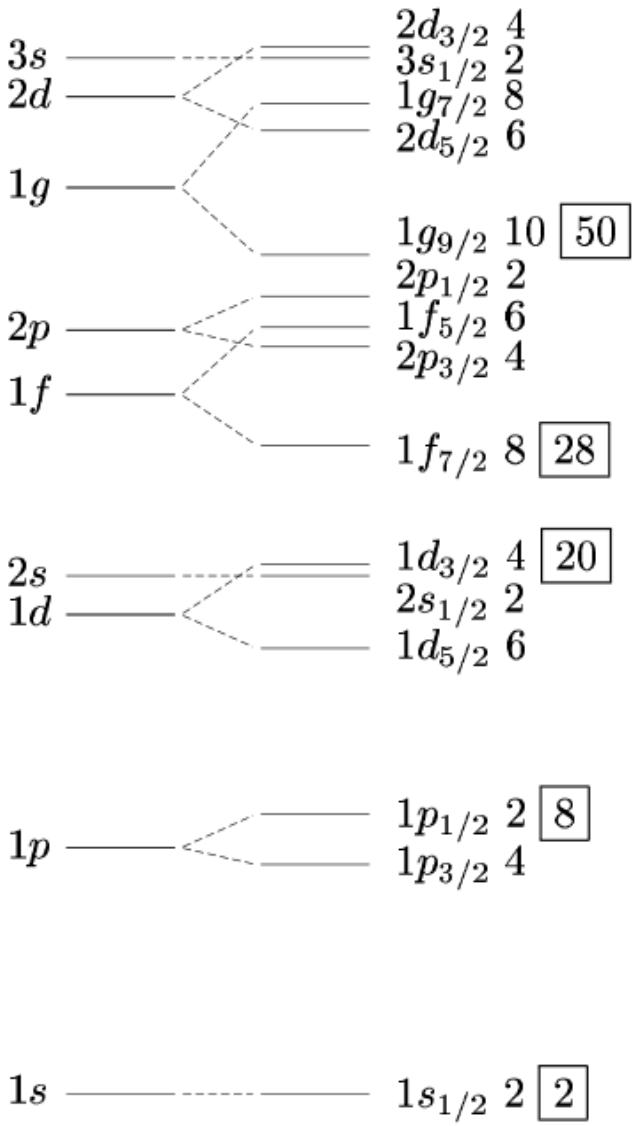
BPU11 Congress
11th International Conference of the Balkan Physical Union
28 August – 1 September 2022, Belgrade, Serbia

Summary

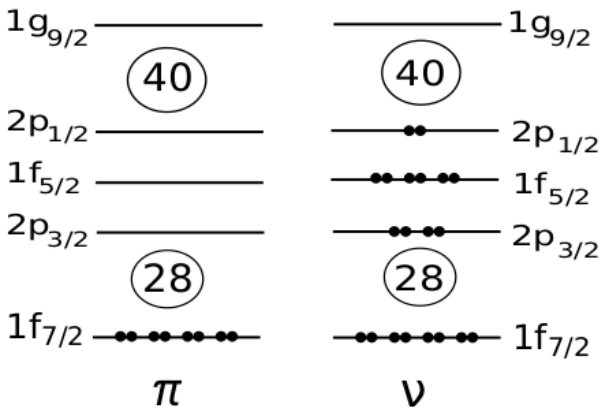
- Nuclear structure around N=40
- Ground state doublet in ^{73}Ga
- Experimental setup
- Lifetime measurements using RDDS
- Results



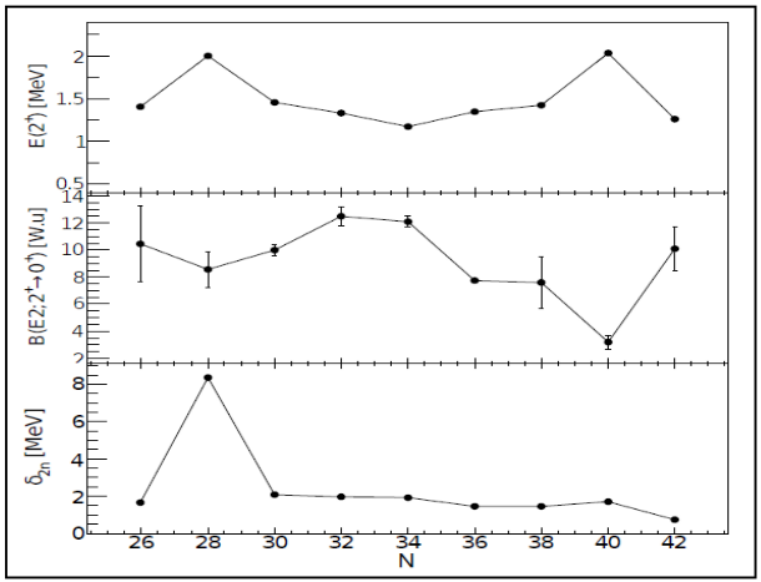
Nuclear structure around N=40, ^{68}Ni



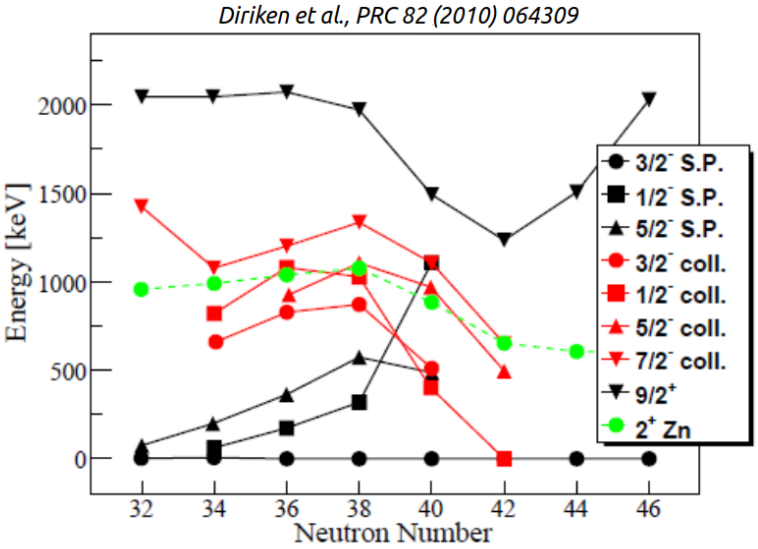
The shell model energy levels



The occupation of proton and neutron orbitals for ^{68}Ni



Magicity parameters in nickel isotopes
(I. Čeliković, Phd. Thesis, Université de Caen Basse-Normandie (2011))



Level energy systematics in odd-mass gallium isotopes

Laser spectroscopy: $1/2^-$ ground state in ^{73}Ga. *(Cheal et al., PRL 104 (2010) 252502)*
^{71}Ga(t,p)^{73}Ga: $3/2^-$ state close in energy to the g.s.

Assuming the existence of a $3/2^-$,$1/2^-$ ground state doublet in ^{73}Ga.

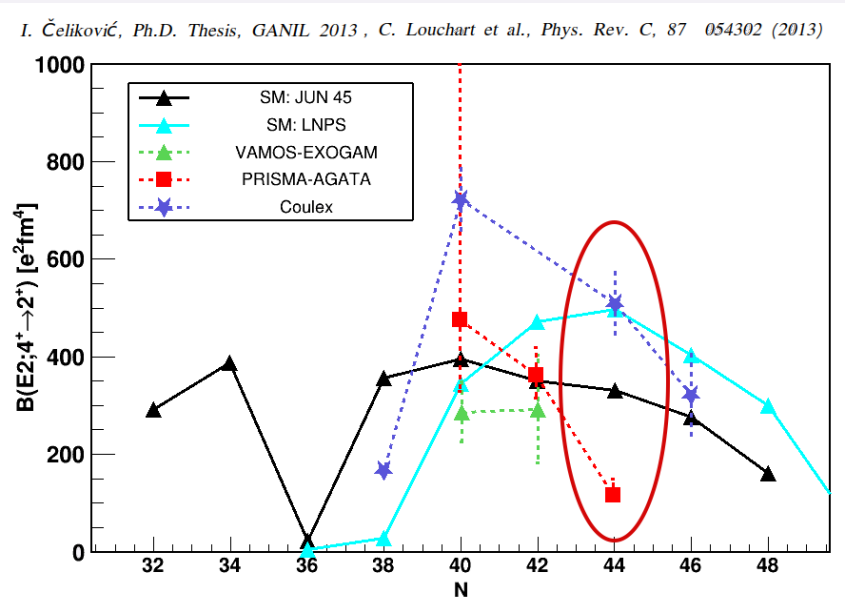
CoulEx measurement suggests the existence of a fast M1 component. *(Diriken et al., PRC 82 (2010) 064309)*

GOALS

Determining the M1 component in the deexcitating transistion from $5/2^-_1$ state in ^{73}Ga.

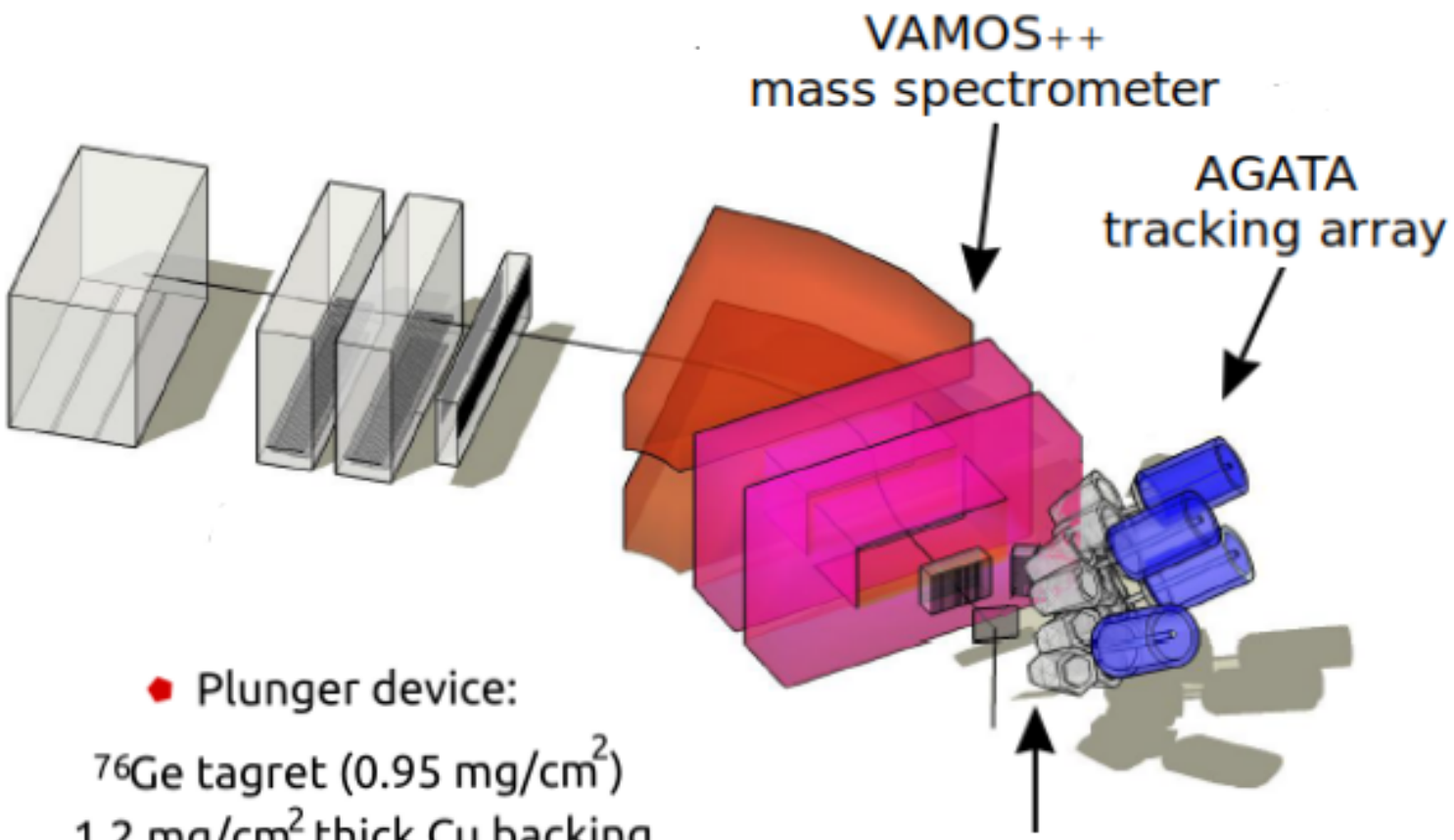
Lifetime measurements of the low-lying states in ^{75,77}Ga.

Solve the discrepancies in ^{74}Zn



B(E2) systematic of even-mass Zn isotopes

Experimental Setup

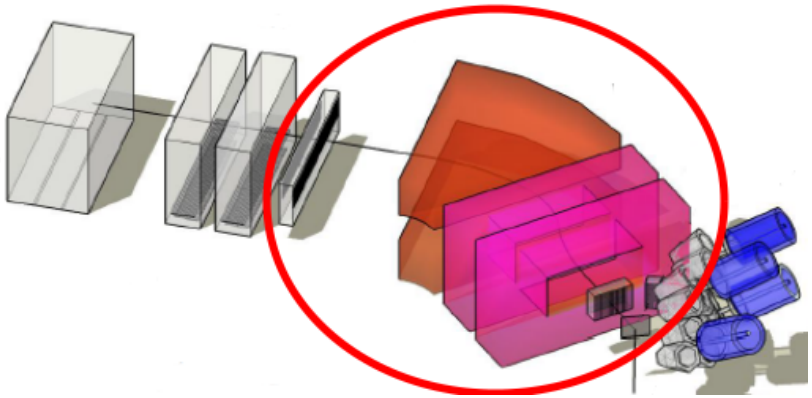


- Plunger device:

^{76}Ge tagret (0.95 mg/cm^2)
1.2 mg/cm^2 thick Cu backing
3 mg/cm^2 Mg degrader

^{208}Pb beam
I=2enA; E=6.63 MeV/A

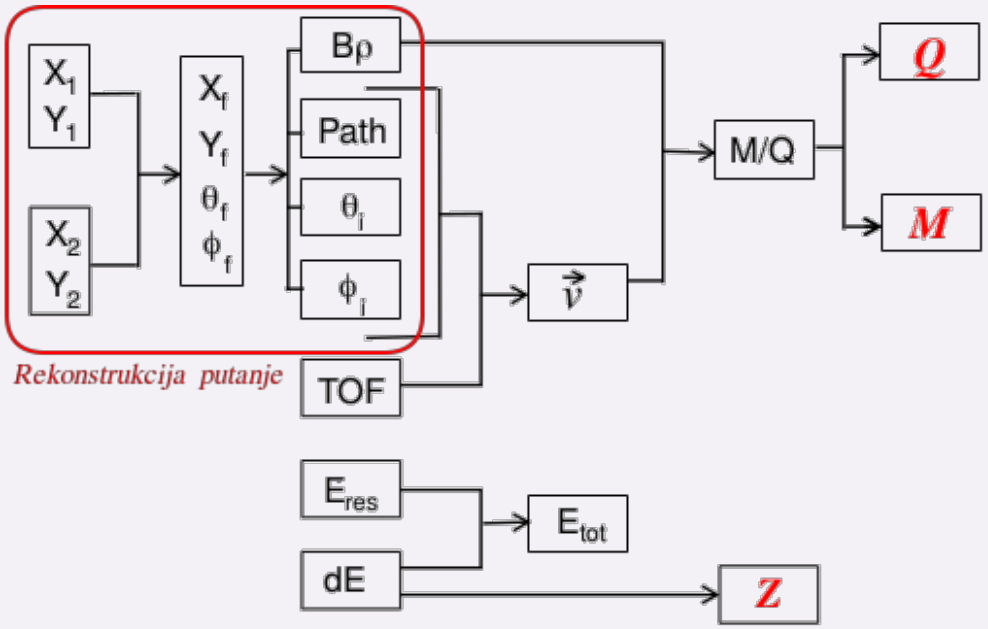
Particle identification in VAMOS++

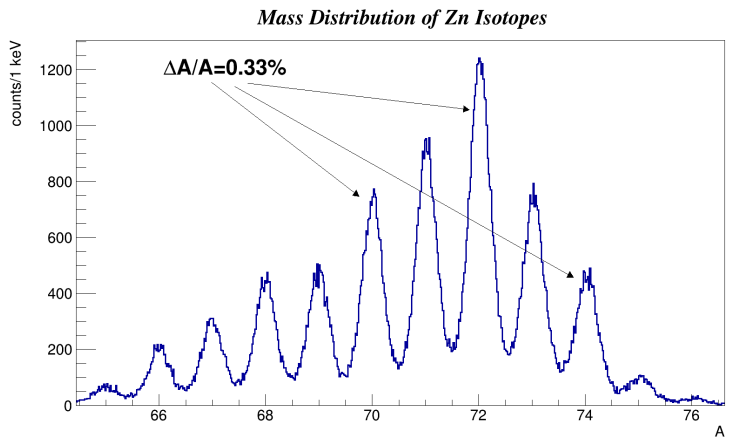


Trajectory reconstruction

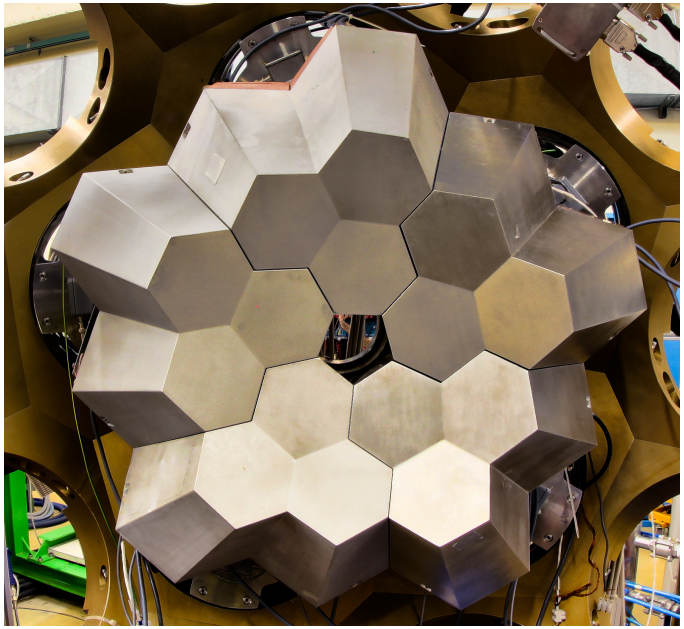
$$\delta = F_1(x_f, \theta_f, y_f, \Phi_f)$$
$$\theta_i = F_2(x_f, \theta_f, y_f, \Phi_f)$$
$$\Phi_i = F_3(x_f, \theta_f, y_f, \Phi_f)$$
$$l = F_4(x_f, \theta_f, y_f, \Phi_f)$$
$$F = \sum_{i,j,k,l=0}^{i+j+k+l=7} C_{ijkl} x_f^i \theta_f^j y_f^k \Phi_f^l$$

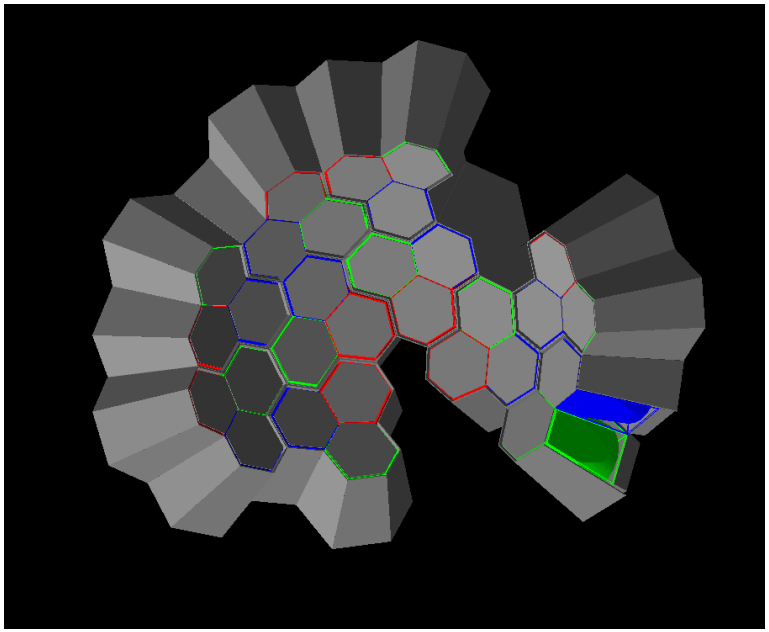
Algorithm of the particle identification



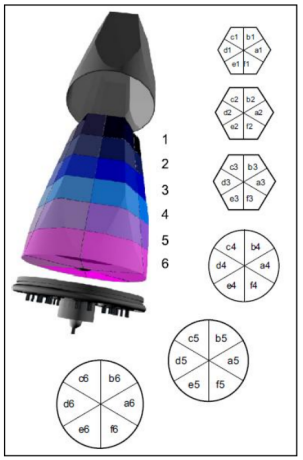


AGATA-Advanced GAmma Tracking Array

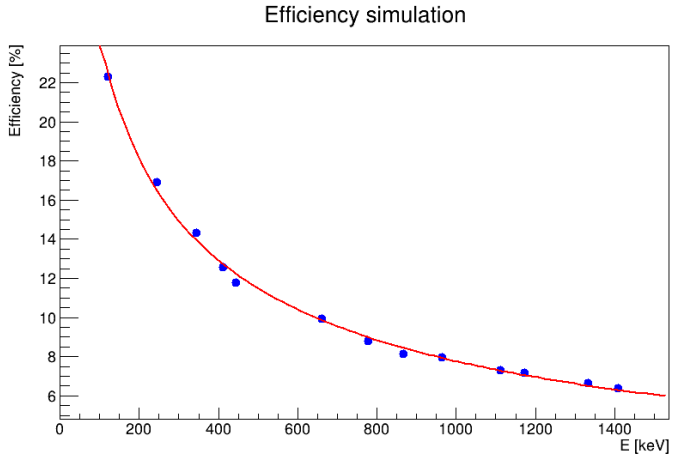




High detection efficiency and energy resolution.



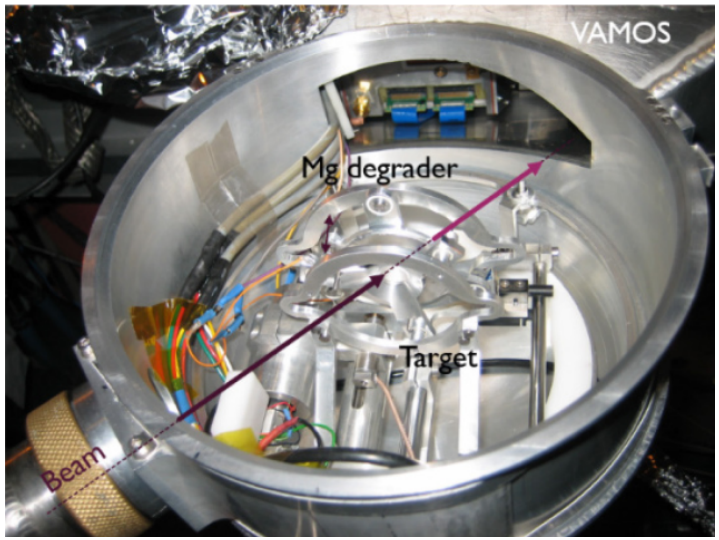
(S. Akkoyun et al. , AGATA-Advanced GAmma Tracking Array, NIM A 668 (2012))



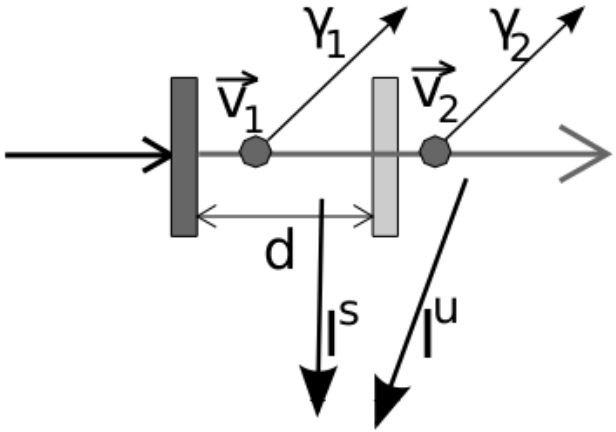
Efficiency curve for 29 crystals

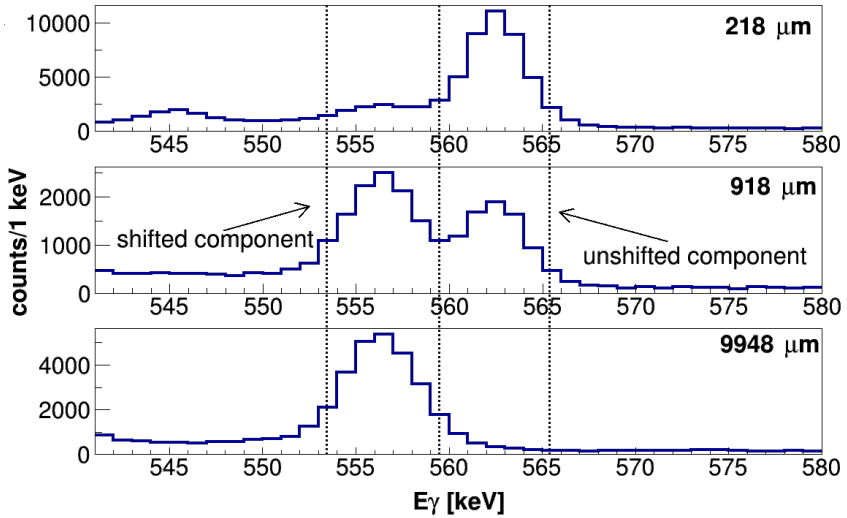
32 crystals in double (ADC) and triple clusters (ATC) (2016.).
All 60 crystals should give 82% space coverage.

Recoil Distance Doppler Shift technique



Cologne plunger device
(C. Stodel et al. EPJ Web of Conferences 229, 05001 (2020))





Differential Decay Curve Method (DDCM):

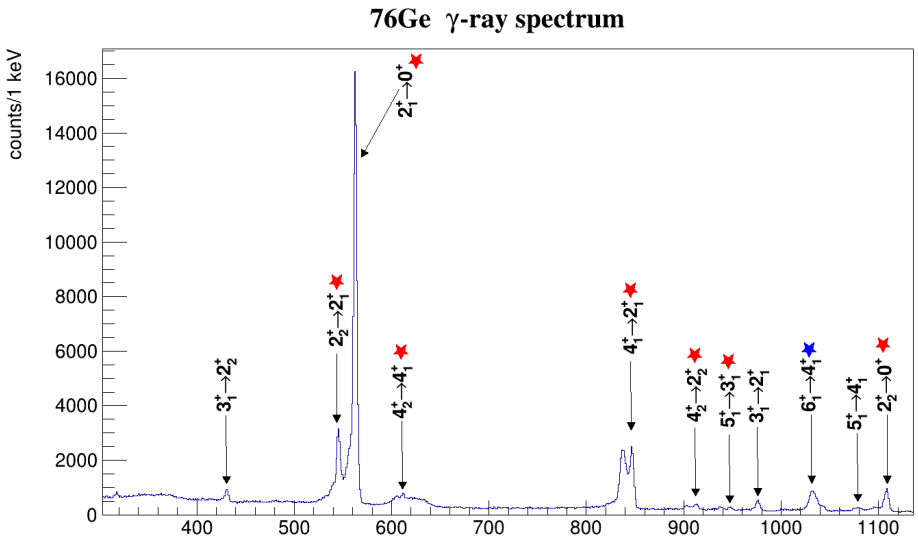
$$Q_{ij}(x) = \frac{I_u(x)}{I_u(x) + I_s(x)}$$

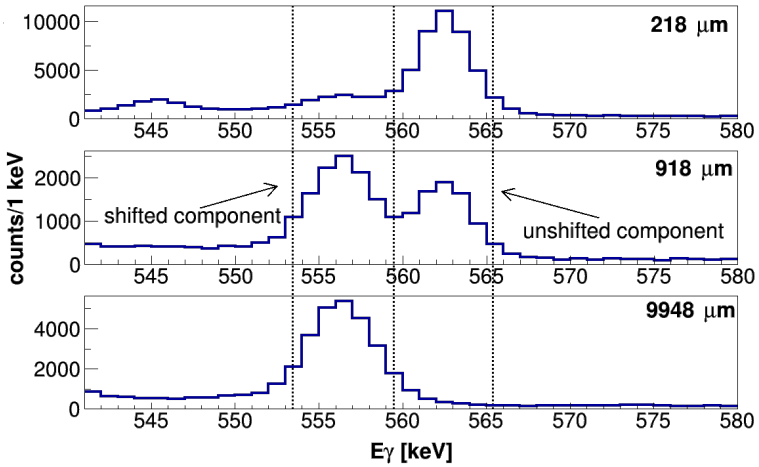
$$\tau(x) = -\left(v\frac{dQ_{ij}(x)}{dx}\right)^{-1}\left(Q_{ij}(x) - \sum_h b\frac{I^s_{hi} + I^u_{hi}}{I^s_{ij} + I^u_{ij}}Q_{hi}(x)\right)$$

$$E_i = E_0\gamma_i(1 - \beta_i\cos\theta)$$

Six target-degrade distances were used: 0.119 mm, 0.218 mm, 0.918 mm, 2.398 mm, 5.035 mm i 9.948 mm.

Method Checkout-Lifetime of 2^+ state in ^{76}Ge



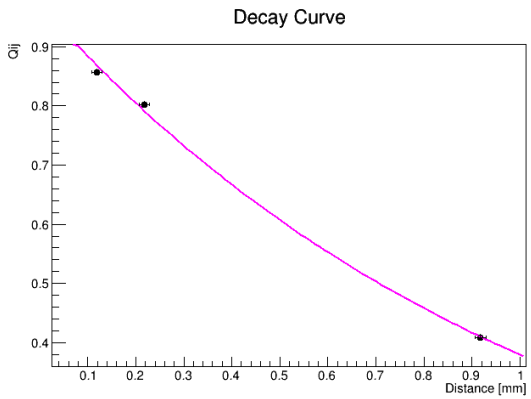


(*T. Milanović, et al., ACTA PHYSICA POLONICA B, 51, 837, 2020.*)

Differential Decay Curve Method (DDCM):

$$Q_{ij}(x) = \frac{I_u(x)}{I_u(x) + I_s(x)}$$

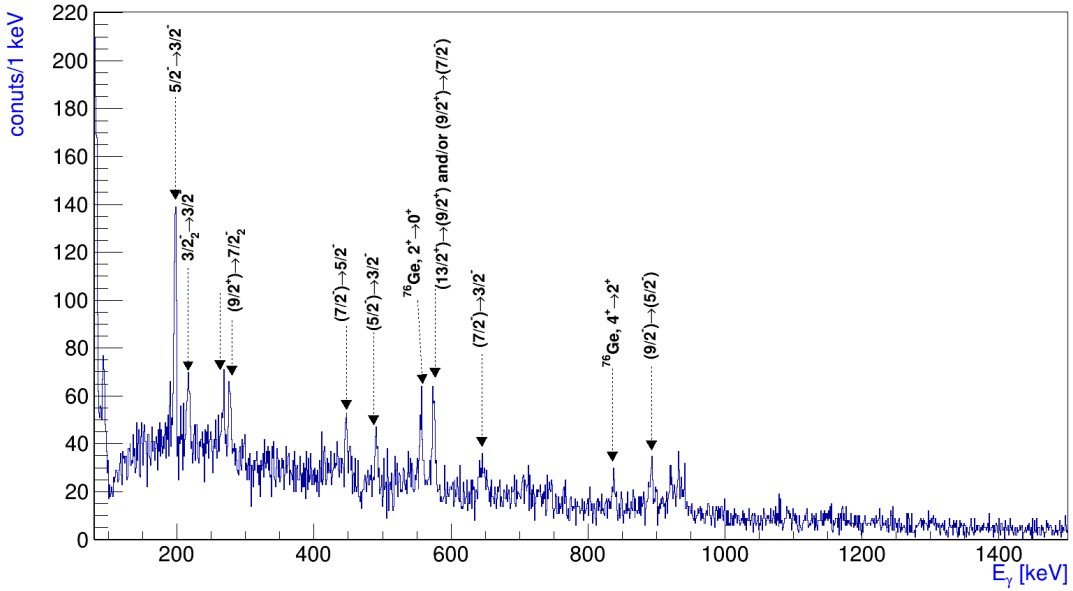
$$\tau(x) = -\left(v\frac{dQ_{ij}(x)}{dx}\right)^{-1}\left(Q_{ij}(x) - \sum_h b\frac{I^s_{hi} + I^u_{hi}}{I^s_{ij} + I^u_{ij}}Q_{hi}(x)\right)$$

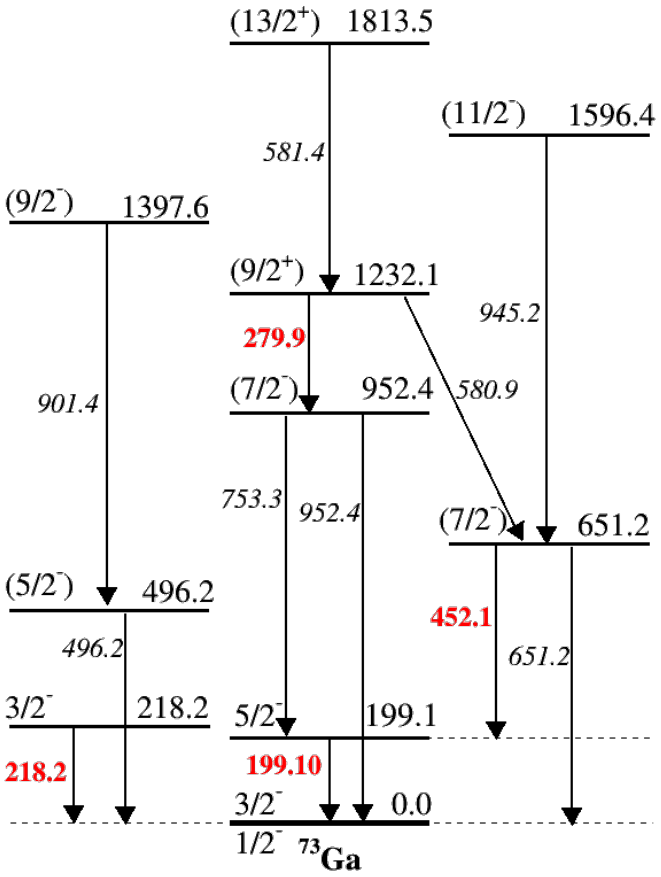


Result: **26.27 ± 0.30 ps**

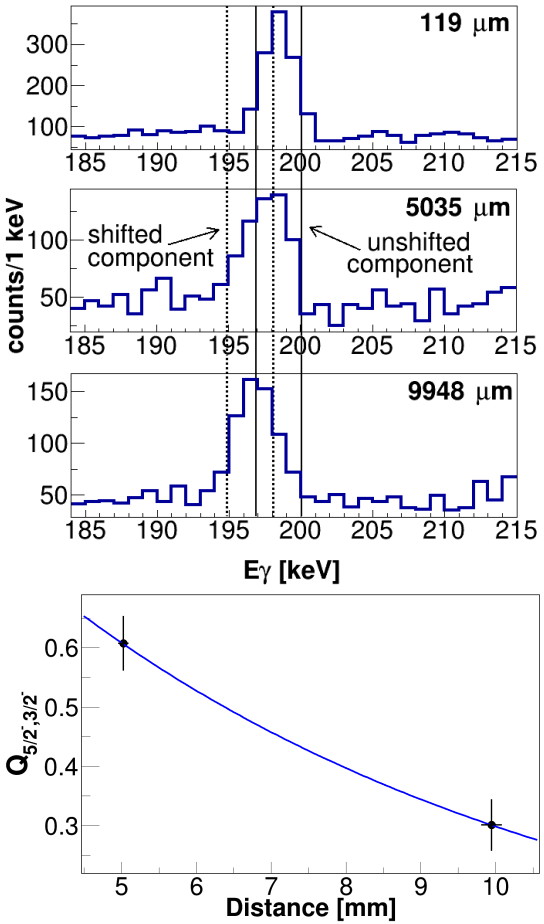
Reported values: 25.93(29) ps R. Lecomte *et al.*, Phys. Rev. C **22**, (1980) 1530.
26.6(6) ps C. Louchart *et al.* Phys. Rev. C **87**, (2013) 054302.

^{73}Ga - γ spectrum and partial level scheme



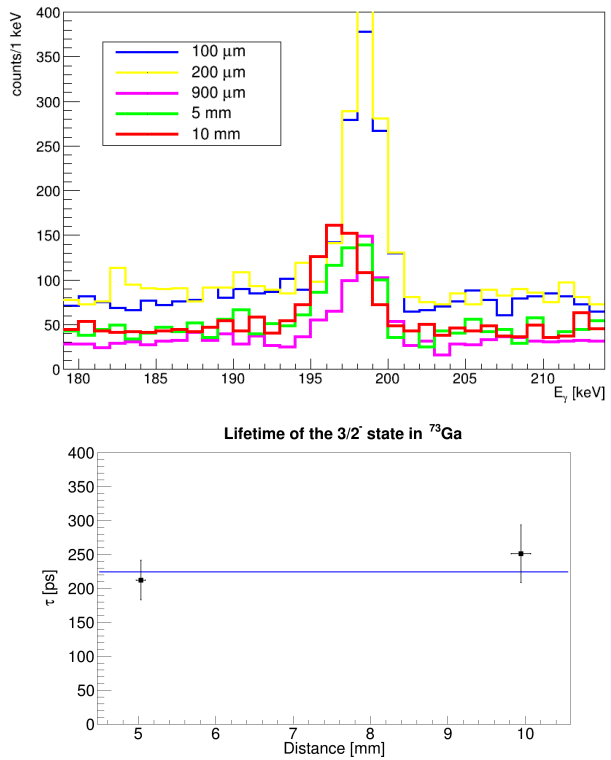


Lifetime measurement of the $5/2_1^-$ state in ^{73}Ga



(*T. Milanović, et al., ACTA PHYSICA POLONICA B, 51, 837, 2020.*)

There is a fast M1 component in the decay of the first $5/2^-$ state. Obtained lifetime confirms $1/2^-$, $3/2^-$ ground state doublet.

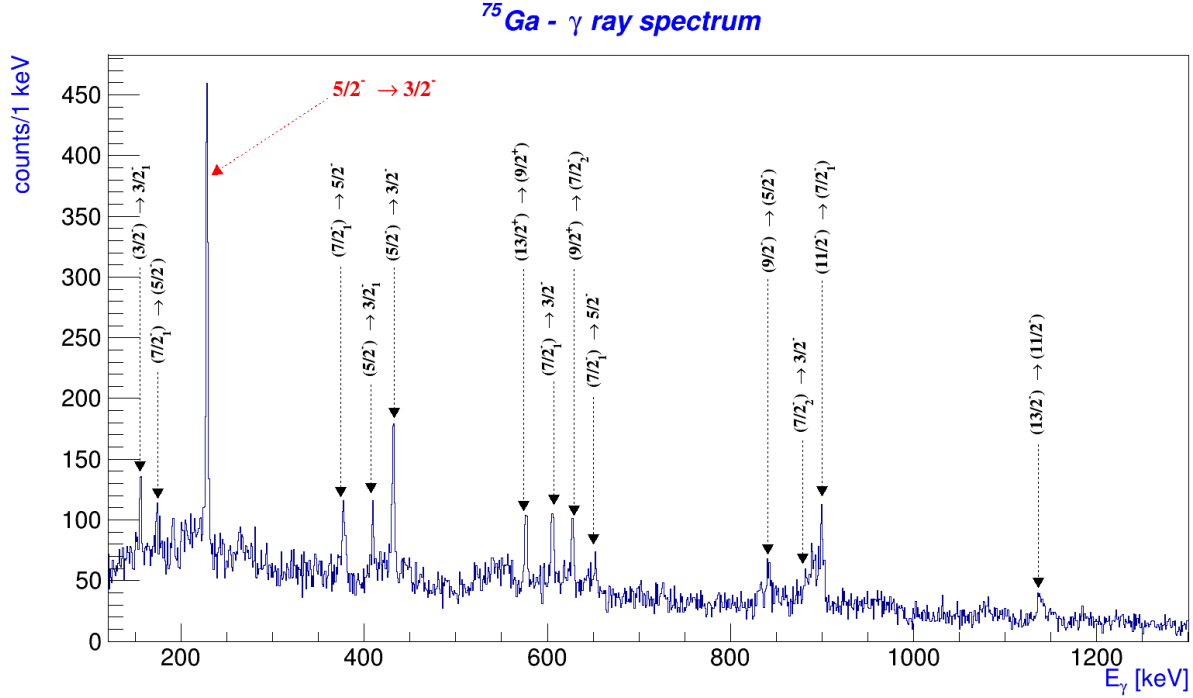


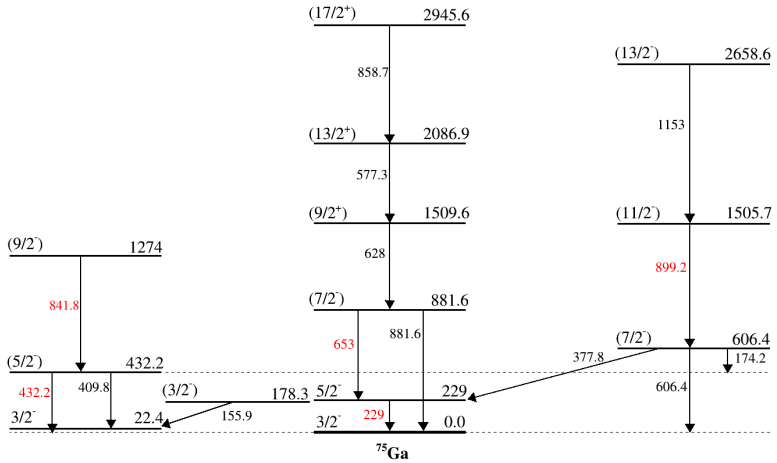
Summary of measured lifetimes in ^{73}Ga

Isotope	J^π	E_γ [keV]	τ_{exp} [ps]	$\tau_W(E2)$ [ps]	$\tau_W(M1)$ [ps]
^{73}Ga	$5/2^-$	199.1	224±24	144*10^3	3.98
	$3/2_2^-$	218.2	40 ±14	92*10^3	3.02
	$(7/2^-)$	452.1	20± 70	2.4*10^3	0.34
	$(9/2^+)$	279.9	$33 \leqslant \tau \leqslant 180$	26.2*10^3	1.43

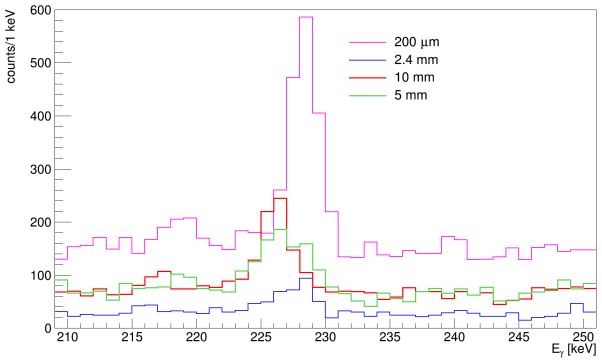
Lifetime of $3/2_2^-$ state measured as 68(9) ps by V. Vedia *et al.* Phys. Rev. C **96**,034311 (2017).

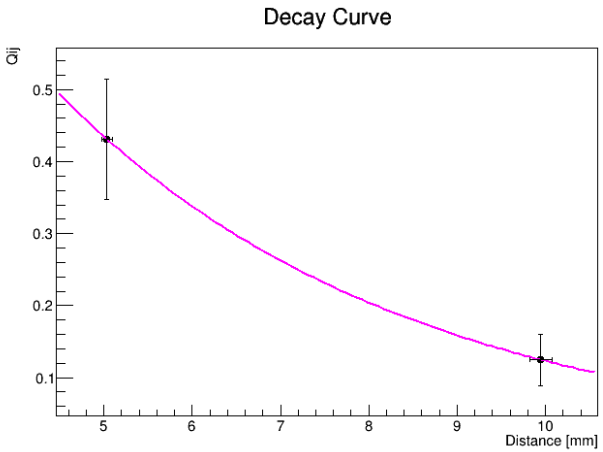
^{75}Ga - γ spectrum and partial level scheme

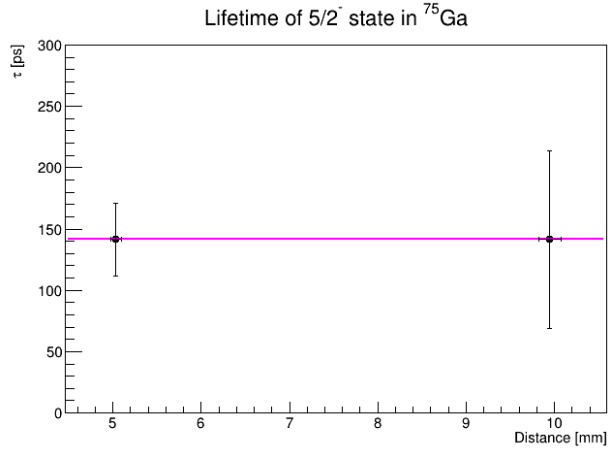




Example: Lifetime measurement of the $5/2^-_1$ state



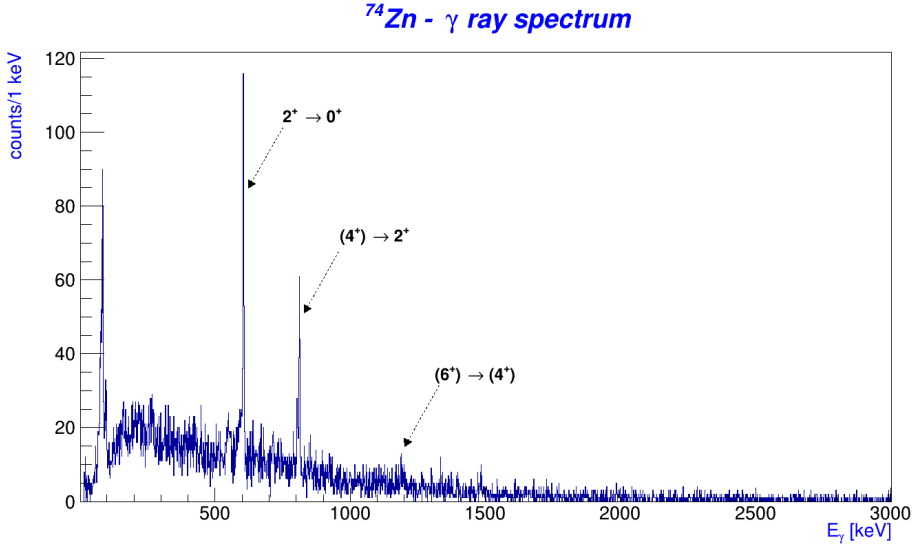




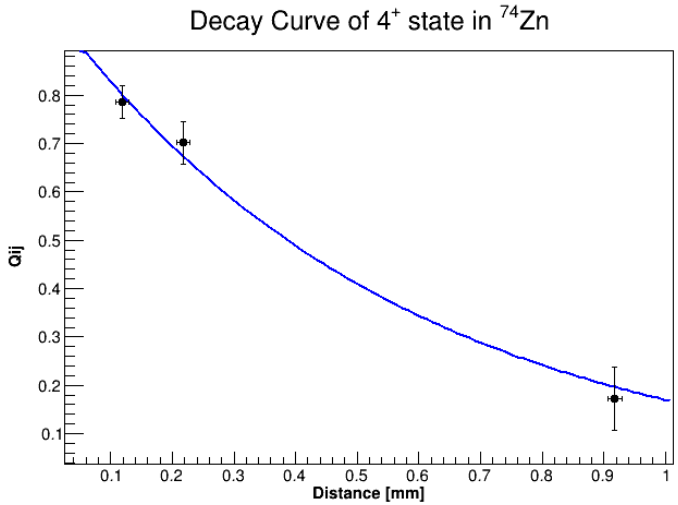
Summary of the measured lifetimes in ^{75}Ga

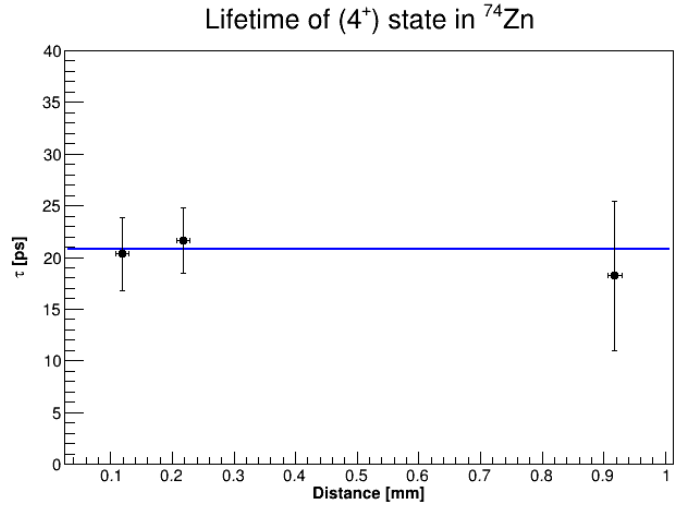
Isotope	J^π	E_γ [keV]	τ_{exp} [ps]	$B(E2;\downarrow)$ [W.u.]	$B(M1;\downarrow)$ [W.u.]
	$5/2^-_1$	229.3	141 ± 27	490±90	0.019±0.004
	$(5/2^-)_2$	432.2	77± 10	40±5	0.005±0.0007
^{75}Ga	$(7/2^-_2)$	652.6	60± 25	6.4±2.6	0.0034±0.0014
	$(9/2^-)$	841.7	8.8± 1.2	12±2	0.006±0.0008
	$(11/2^-)$	899.2	5.7± 0.4	14.0±0.9	0.008±0.0005

Physics goal 2: Lifetime measurement of 4^+ state in ^{74}Zn



γ spectrum at 119 μm target-degrader distance

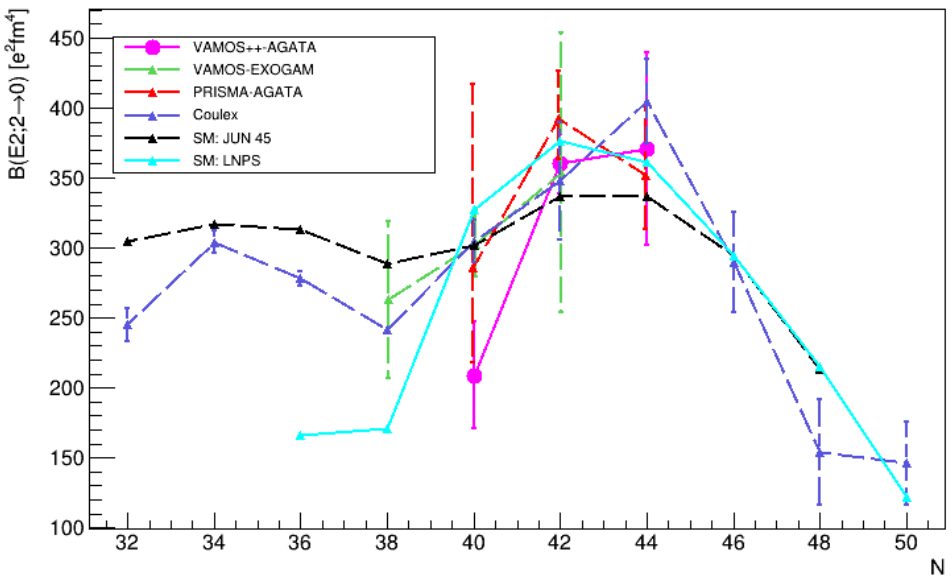


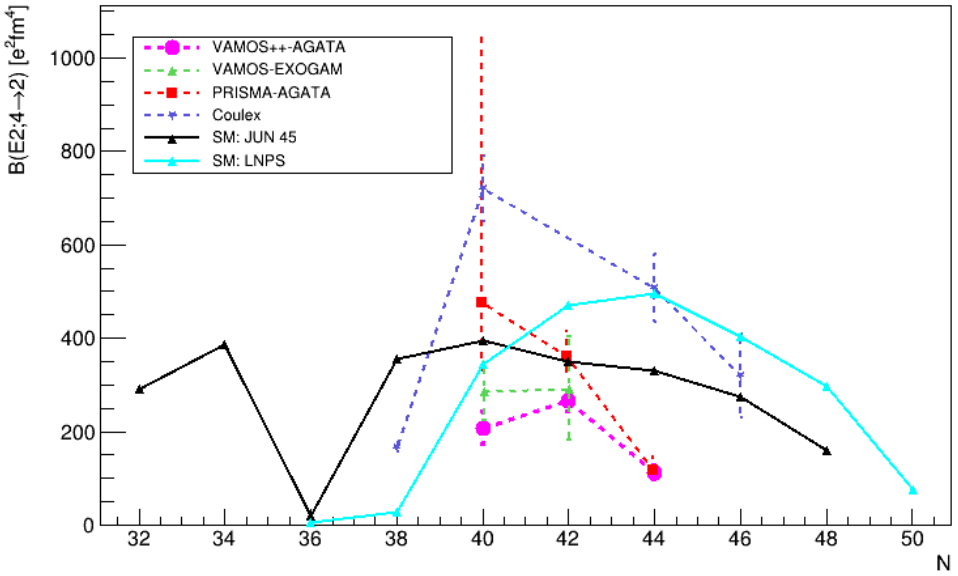


$\tau = 20.8(22)$ ps

State	B(E2;↓) [e^2fm^4]				
	Experiment			*Theory*	
	VAMOS-AGATA	*Louchart et al.*	*Previous works*	*SM JUN45*	*SM LNPS*
2^+	242±32	352^{+50}_{-39}	400 ± 20	339	361
4^+	111±12	116^{+32}_{-10}	507 ± 74	336	496
6^+	-	-	-		

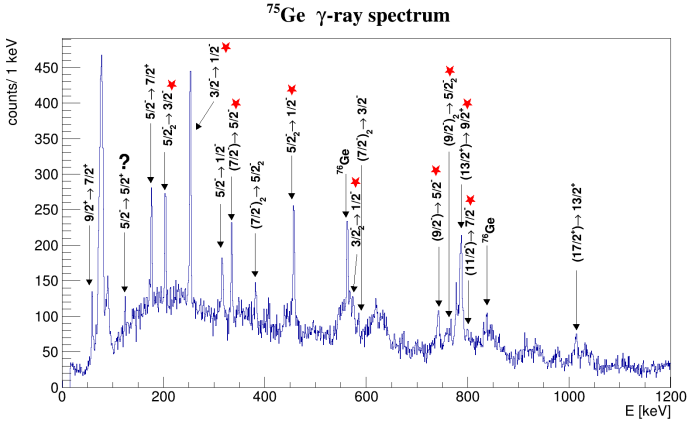
Systematics of B(E2) transitions in even-mass Zn isotopes

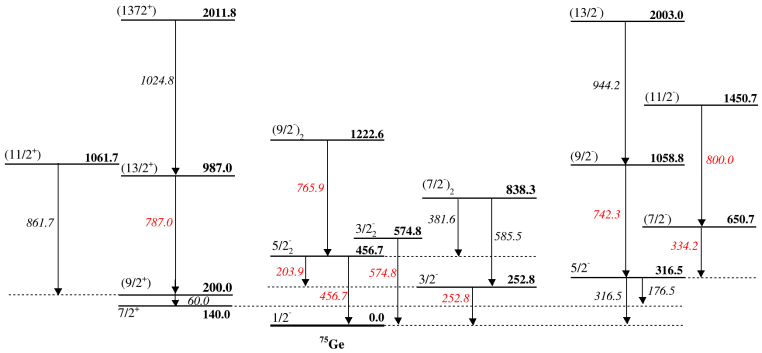




- Results obtained using RDDS data with γ singles.
- $B(E2; 4^+ \rightarrow 2^+)$ values in ^{74}Zn obtained in different experiments using RDDS method are in agreement.

Additionally analysed isotopes





Lifetime measurements also performed in ^{75}Ge, ^{76}Ge, ^{77}Ge, ^{78}Ge and ^{79}Ge, many of extracted lifetimes are measured for the first time (makred red in table).

Isotope	Transition	E_γ [keV]	τ_{exp} [ps]	Previous results
^{75}Ge	$5/2_2^- \rightarrow 3/2^-$	203.9	$8 \leqslant \tau \leqslant 33$	x
	$3/2^- \rightarrow 1/2^-$	252.8	64± 16	x
	$(7/2^-) \rightarrow 5/2^-$	334.2	$8 \leqslant \tau \leqslant 33$	x
	$5/2_2^- \rightarrow 1/2^-$	456.7	$8 \leqslant \tau \leqslant 33$	x
	$3/2_2^- \rightarrow 3/2^-$	574.8	< 4	x
	$(9/2^-) \rightarrow 5/2^-$	742.3	< 8	x
	$(9/2^-)_2 \rightarrow 5/2_2^-$	765.9	9.1± 2.5	x
	$(13/2^+) \rightarrow (9/2^+)$	787.0	7.8± 0.4	x
	$(11/2^-) \rightarrow (7/2^-)$	800.0	5.4± 1.3	x
^{76}Ge	$2^+ \rightarrow 0^+$	562.9	27.4± 0.3	26.3±0.3 (Coul. Ex.)
	$4_2^+ \rightarrow 4^+$	611.7	3.3± 0.3	x
	$4^+ \rightarrow 2^+$	847.15	3.14± 0.06	2.6±0.6 (Coul. Ex.)
	$5^+ \rightarrow 3^+$	947.8	3.1± 0.7	x
	$6^+ \rightarrow 4^+$	1043.7	<4.3	x
	$2_2^+ \rightarrow 0^+$	1108.4	12.2± 0.5	11.5±2.1 (Coul. Ex.)
^{77}Ge	$9/2^+ \rightarrow 7/2^+$	225.0	88± 5	x
	$5/2^+ \rightarrow 7/2^+$	421.4	370± 40	x
	$(3/2^+) \rightarrow 1/2^-$	459.2	96± 12	x
	$3/2^+ \rightarrow 1/2^-$	470.0	5.8± 0.5	x
	$5/2^- \rightarrow 9/2^+$	492.0	140±13	x
	$5/2_2^+ \rightarrow 7/2^+$	504.8	52± 7	x
	$7/2_2^+ \rightarrow 9/2^+$	535.5	<4	x
	?	584.6	30±14	x
	$x \rightarrow 7/2^+$	809.0	4.47±0.24	x
	$5/2_3^+ \rightarrow 7/2^+$	884.0	4.70± 0.18	x
^{78}Ge	$2^+ \rightarrow 0^+$	619.2	26.4± 1.2	23±4 (fast timing)
	$4^+ \rightarrow 2^+$	950.6	5.3± 0.6	<5.05 (fast timing)
^{79}Ge	?	1044	12± 4	x

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THANK YOU FOR YOUR ATTENTION