



# Testing ab-initio calculations in light nuclei via high-precision spectroscopy

Irene Zanon

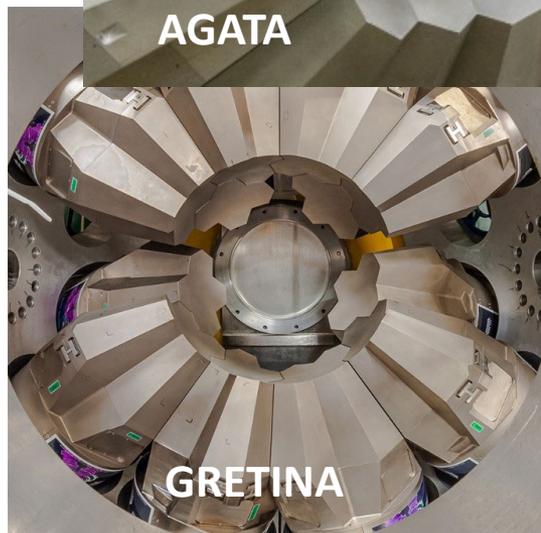
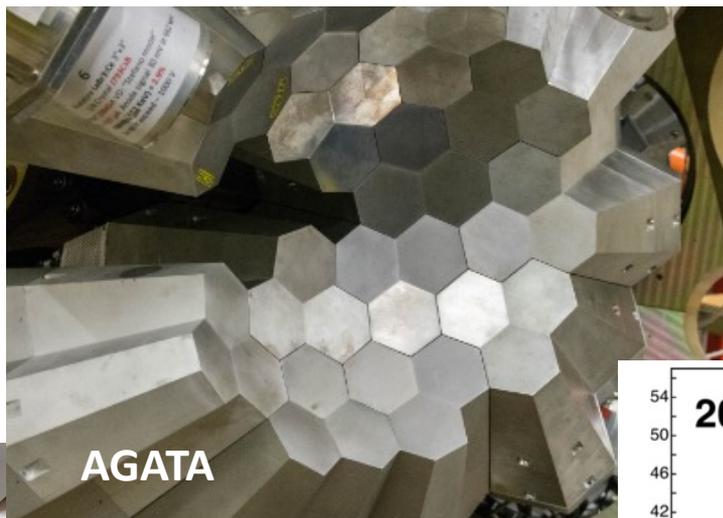
*INFN – Laboratori Nazionali di Legnaro*

ARIS 2023

6th June

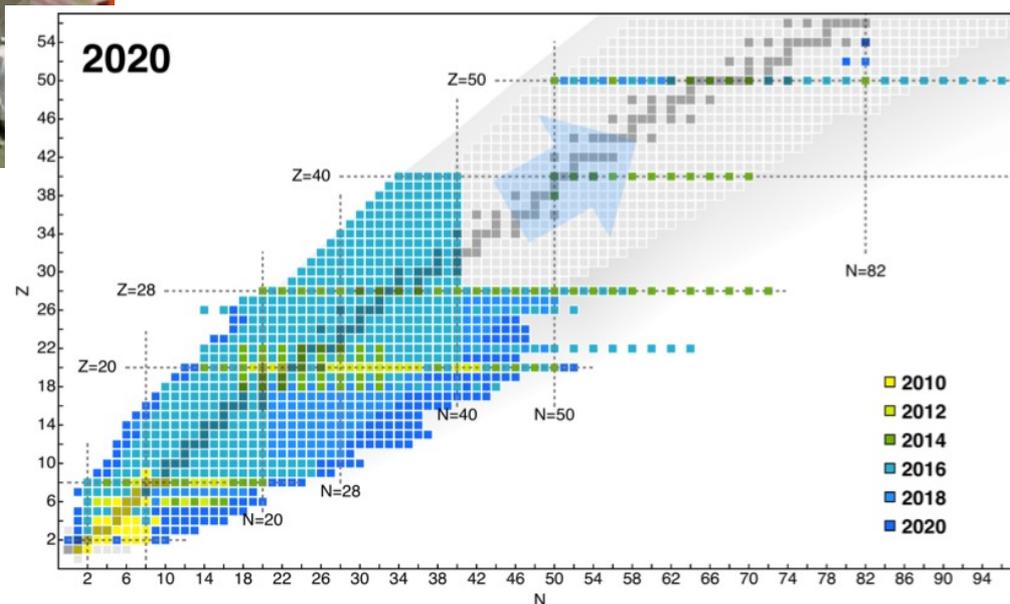


# The role of ab-initio calculations



Improvements of experimental setups

Improvements of theoretical models



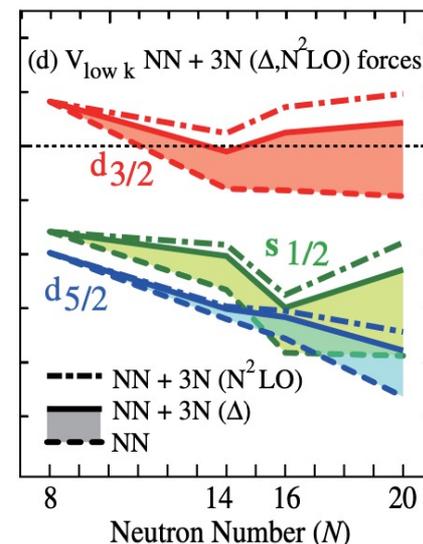
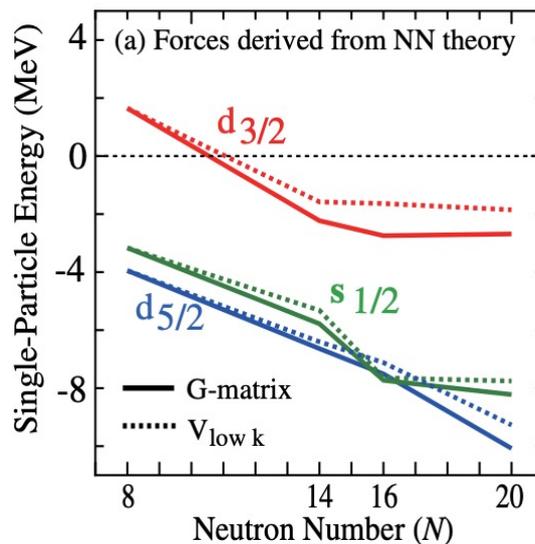
H. Hergert, *Front. in Phys.* 8 (2020)

# The $^{20}\text{O}$ studycase

Z	18Ne 1.6670 S ε: 100.00%	19Ne 17.22 S ε: 100.00%	20Ne STABLE 90.48%	21Ne STABLE 0.27%	22Ne STABLE 9.25%	23Ne 37.24 S β-: 100.00%	24Ne 3.38 M β-: 100.00%
9	17F 64.49 S ε: 100.00%	18F 109.77 M ε: 100.00%	19F STABLE 100%	20F 11.07 S β-: 100.00%	21F 4.158 S β-: 100.00%	22F 4230 MS β-: 100.00% β-n < 11.0%	23F 2230 MS β-: 100.00% β-n < 14.00%
8	16O STABLE 99.757%	17O STABLE 0.038%	18O STABLE 0.205%	19O 26.88 S β-: 100.00%	<b>20O 13.51 S β-: 100.00%</b>	21O 3.42 S β-: 100.00%	22O 2250 MS β-: 100.00%
7	15N STABLE 0.364%	16N 7.13 S β-: 100.00% β-α: 1.2E-3%	17N 4171 MS β-: 100.00% β-n: 95.10%	18N 619 MS β-: 100.00% β-α: 12.20%	19N 336 MS β-: 100.00% β-n: 41.80%	20N 136 MS β-: 100.00% β-n: 42.90%	
6	14C 5700 Y β-: 100.00%	15C 2.449 S β-: 100.00%	16C 0.747 S β-: 100.00% β-n: 99.20%	17C 191 MS β-: 100.00% β-n: 28.40%	18C 92 MS β-: 100.00% β-n: 22.00%	19C 46.2 MS β-: 100.00% β-n: 47.00%	
	8	9	10	11	12	13	

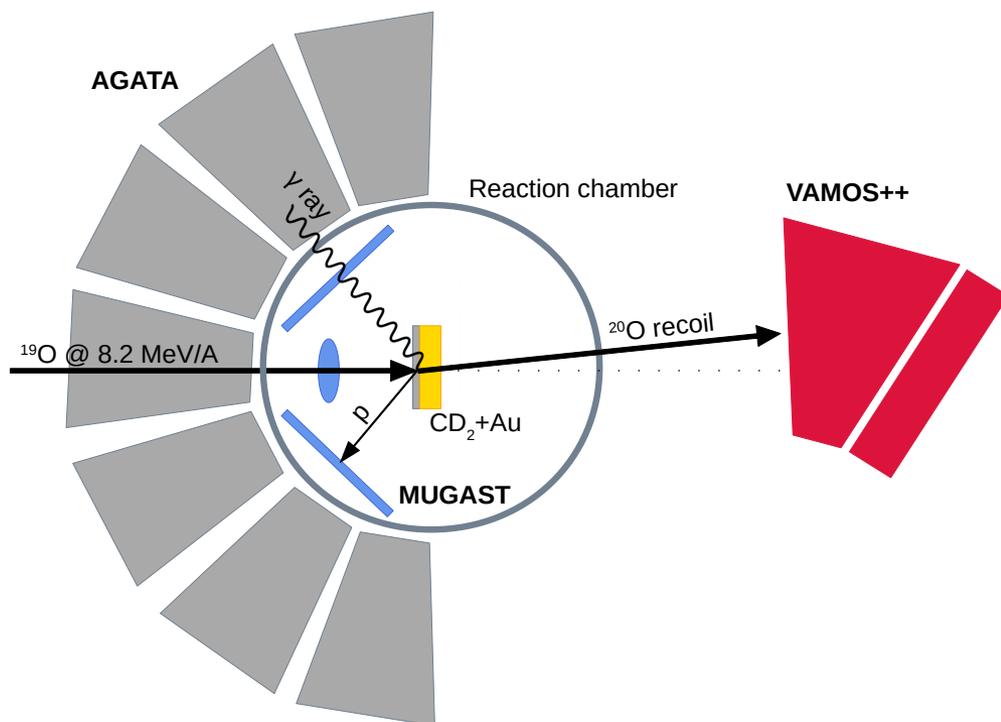
Oxygen isotopic chain  
explored for the role of 3N  
forces

The  $^{20}\text{O}$  is half-way between the  
valley of stability and the neutron  
dripline



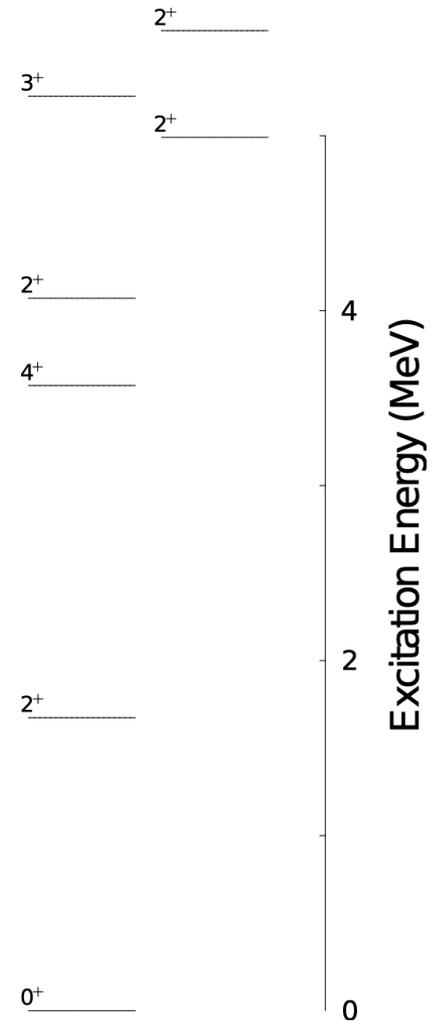
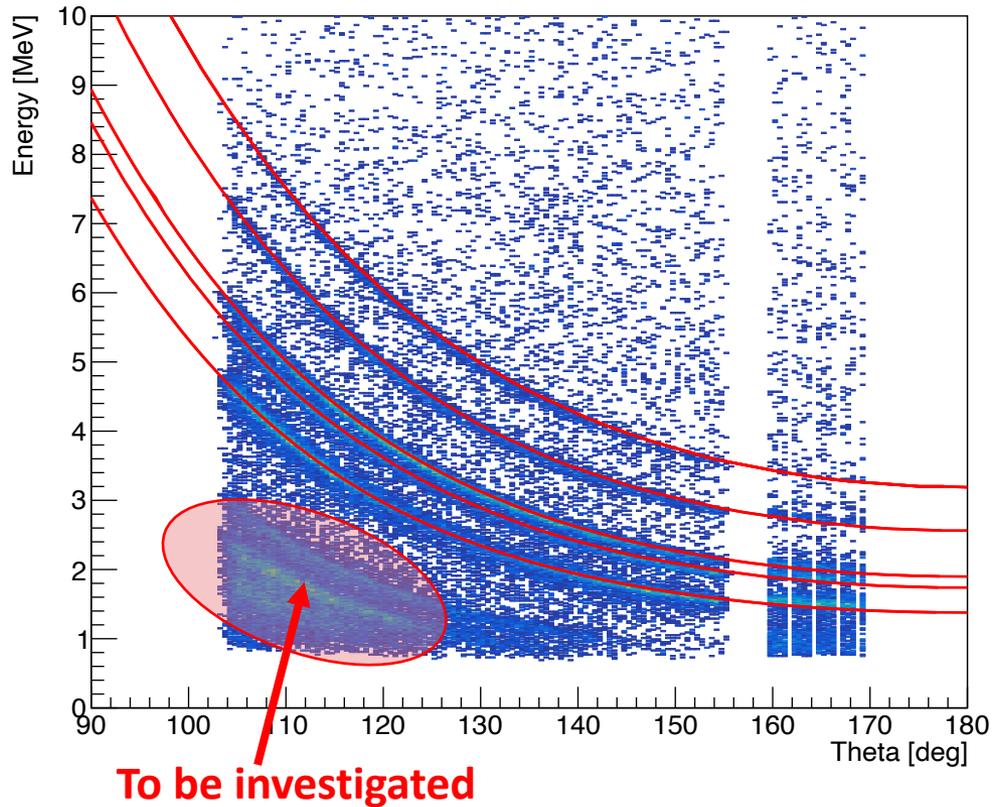
T. Otsuka et al., PRL **104**, 012501 (2010)

# The experiment



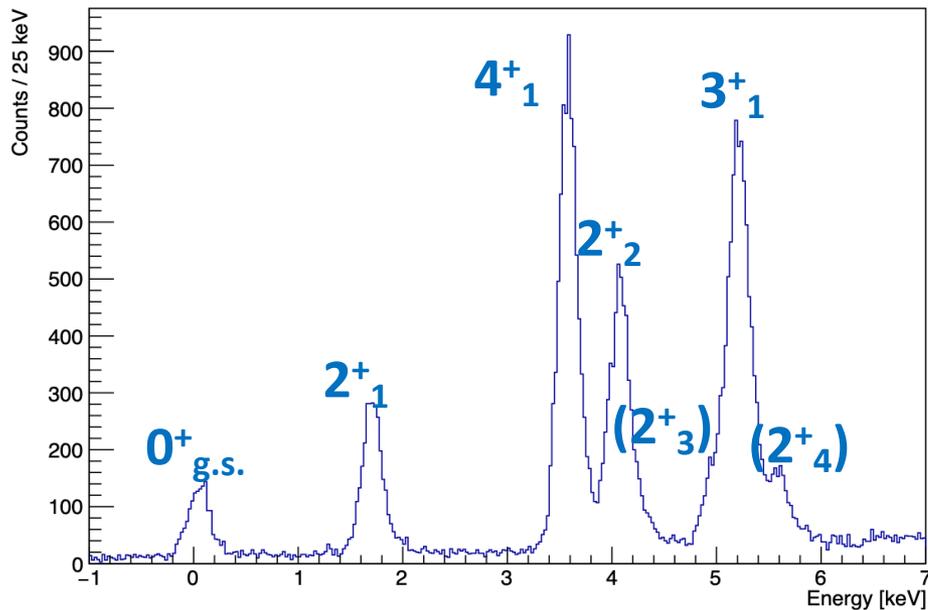
- $^{19}\text{O}(d,p)^{20}\text{O}$  reaction
- Beam  $^{19}\text{O}$  8 MeV/A  
i:  $4 \times 10^5$  pps  
99% purity
- Target  $\text{CD}_2$  0.3 mg/cm<sup>2</sup>  
+ Au 24.4 mg/cm<sup>2</sup>
- Spectroscopy + DSAM
- AGATA array +  
MUGAST + VAMOS

# Excited states

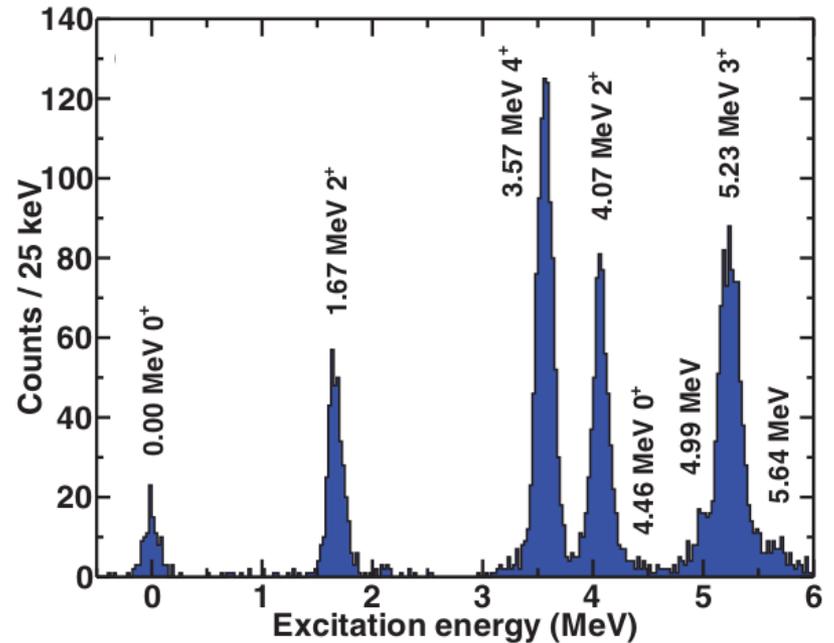
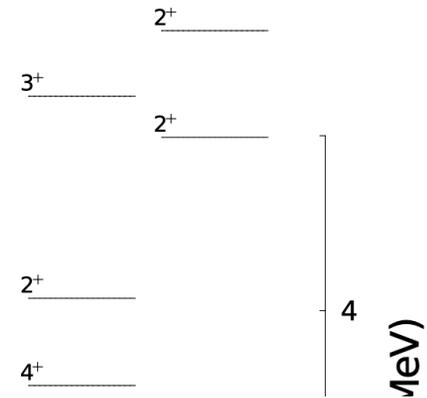


# Excited states

Seven excited states were identified below the  $S_n$  threshold.



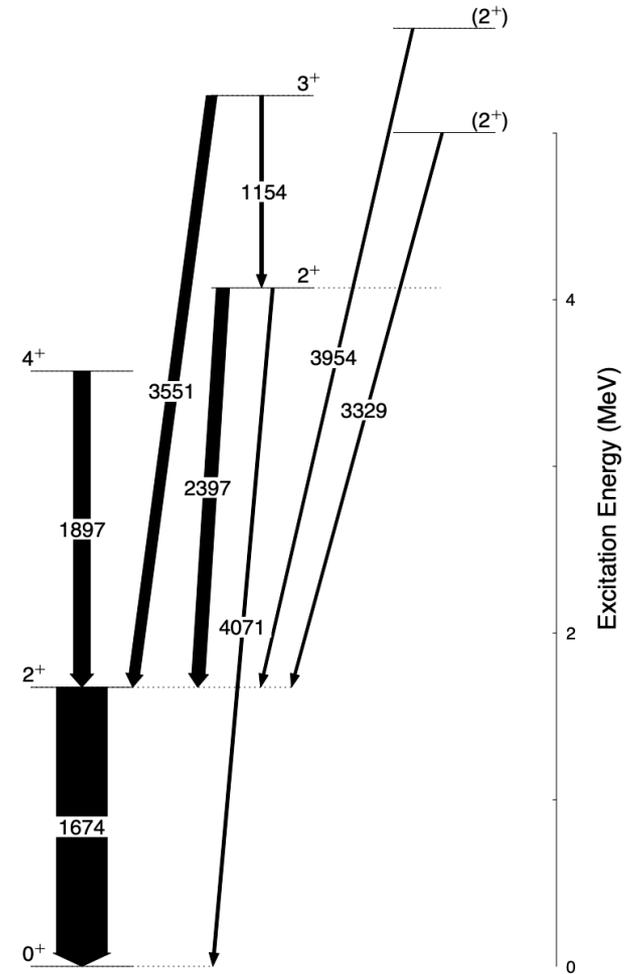
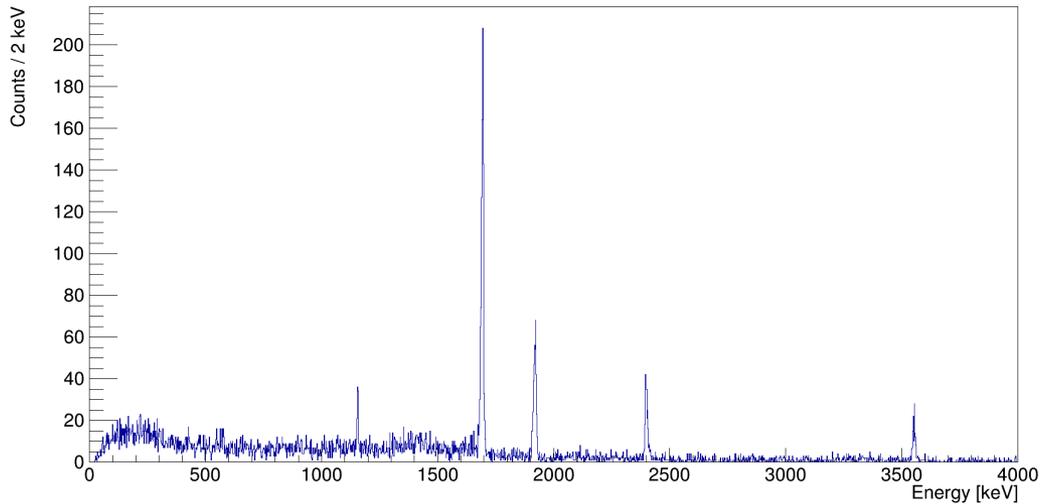
This work



C. Hoffman et al., PRC **85**, 054318 (2012)

# Excited states

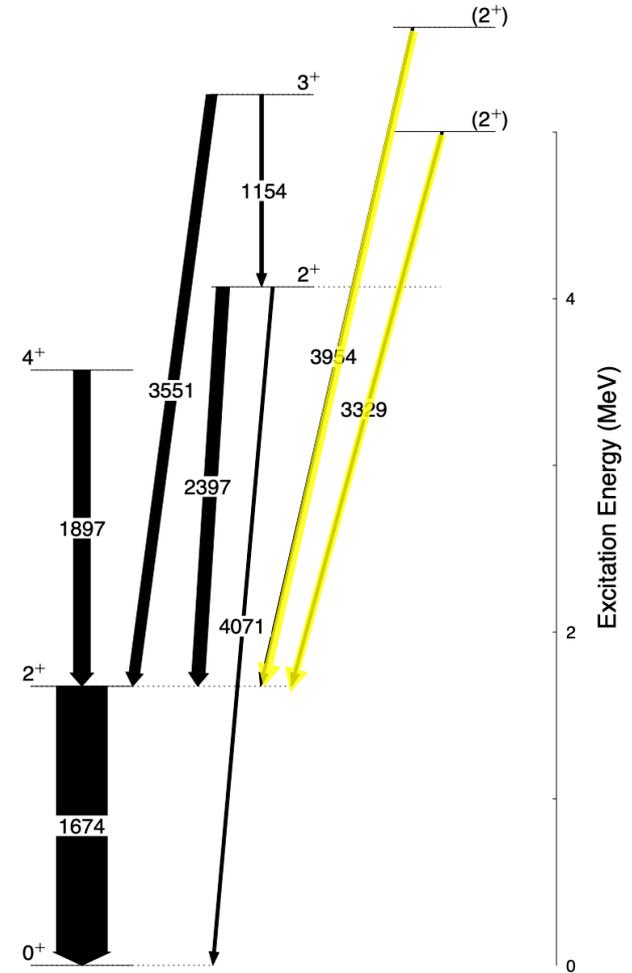
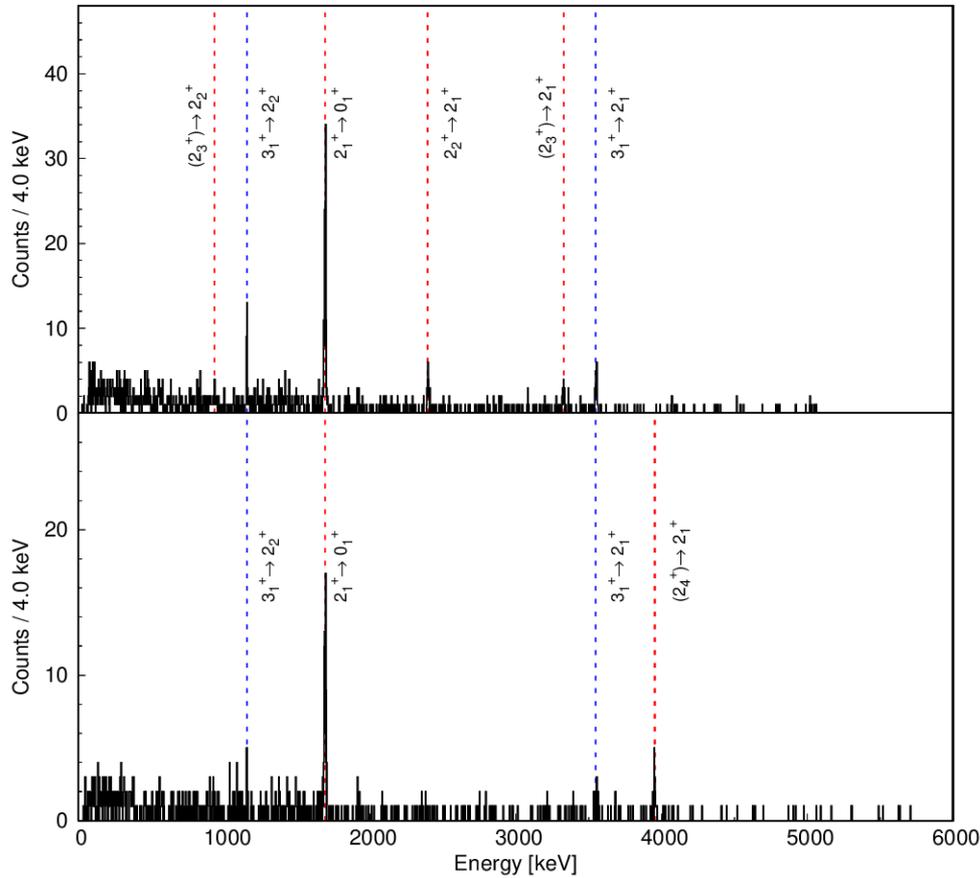
By gating on the excitation energy spectrum, it was possible to reconstruct the level scheme of the  $^{20}\text{O}$  nucleus.



# Excited states

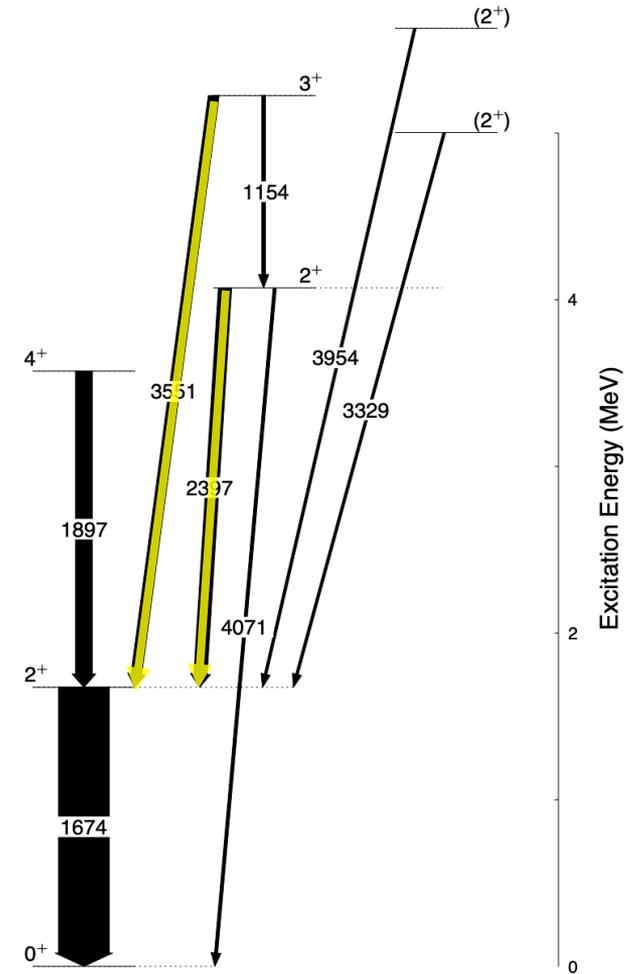
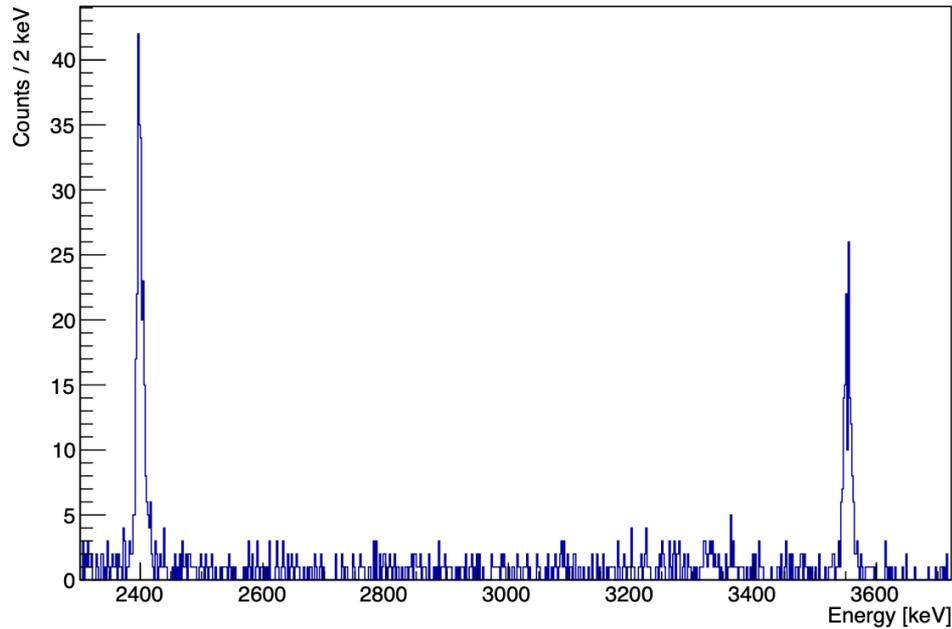
Gate 4.9 MeV

Gate 5.6 MeV



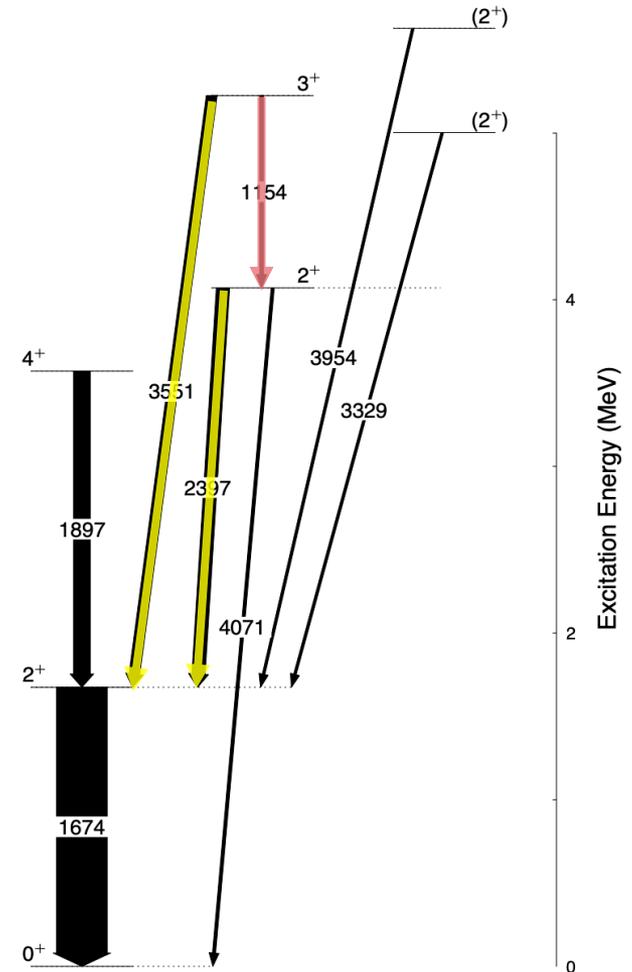
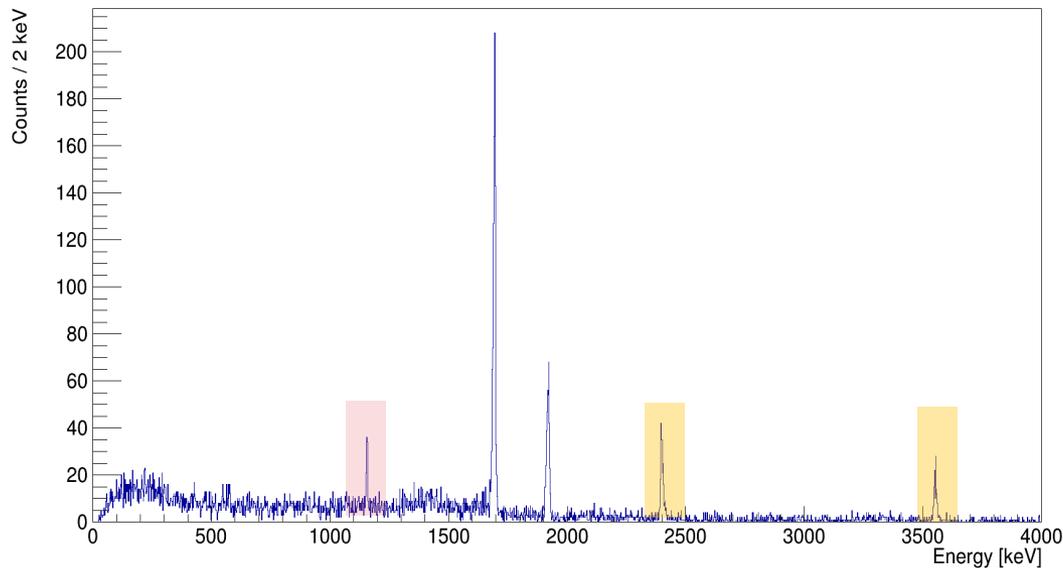
# Excited states

Feeder-free gate on the two states of interest allowed for the study of the line-shape of two transitions



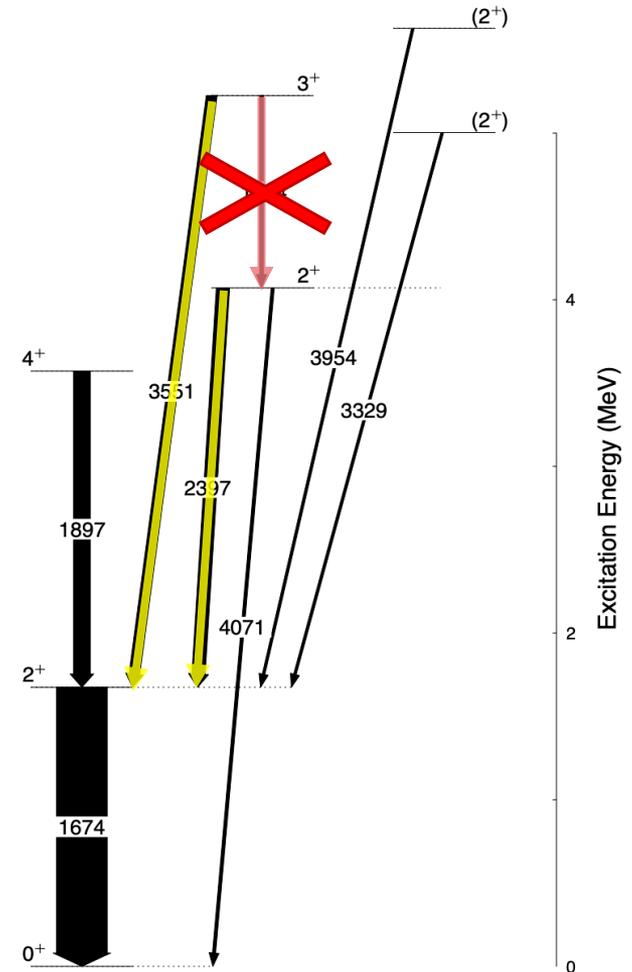
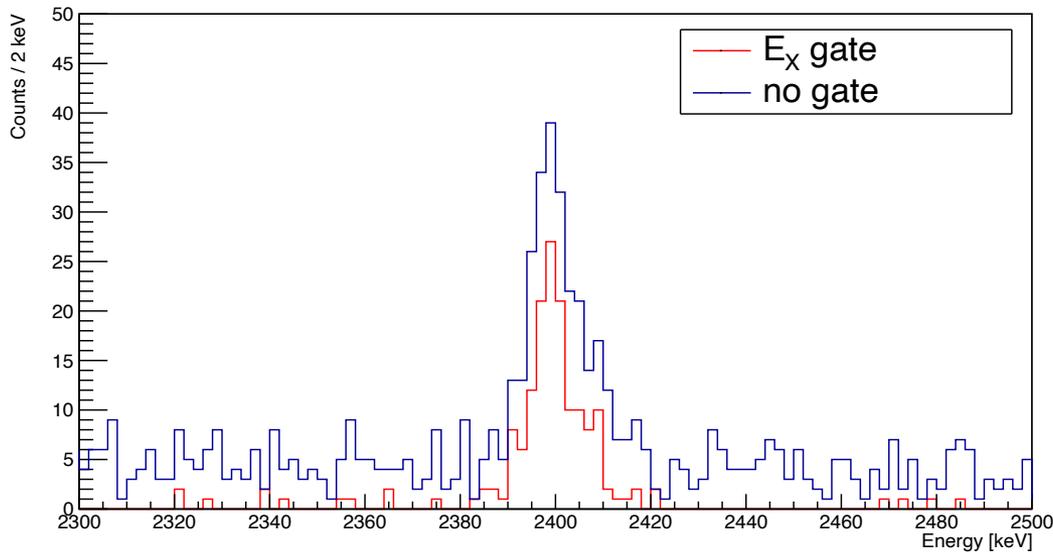
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Feeder-free gate on the two states of interest allowed for the study of the line-shape of two transitions



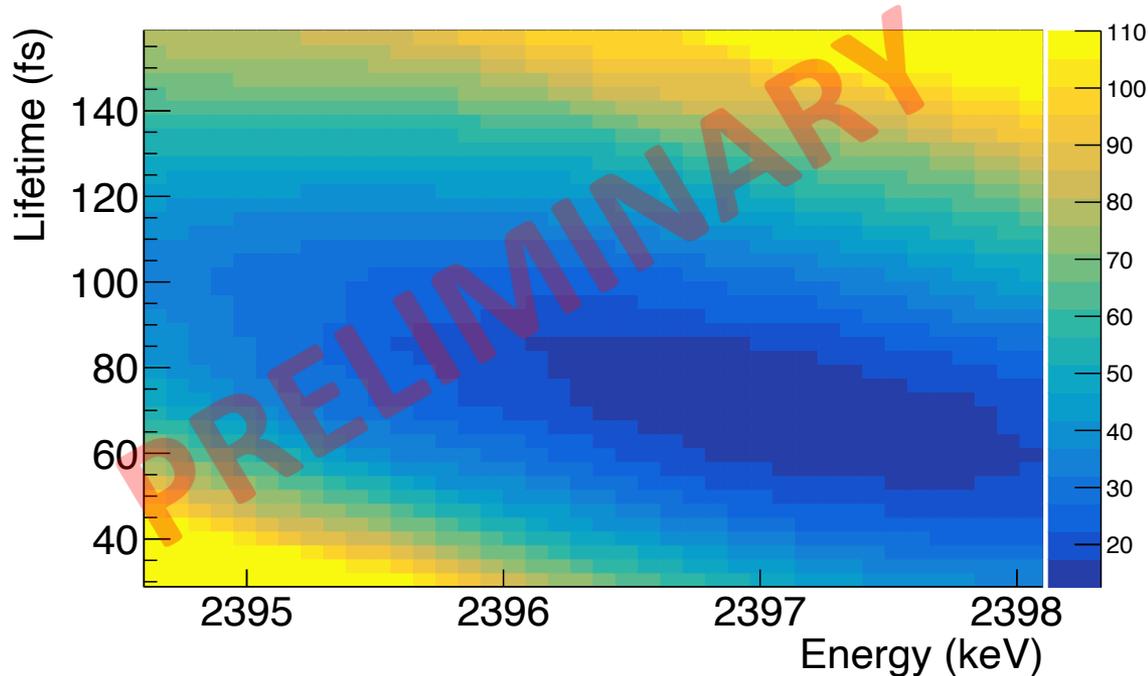
# Excited states

Feeder-free gate on the two states of interest allowed for the study of the line-shape of two transitions



# Lifetime measurements

The lifetime measurement is extracted by fitting the lineshape of the transition to Monte Carlo simulations performed with Geant4.

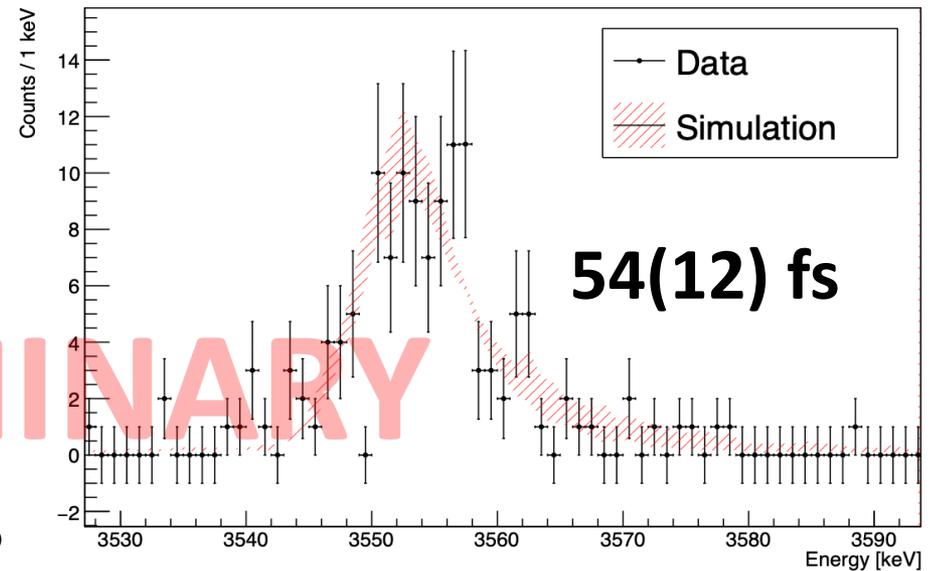
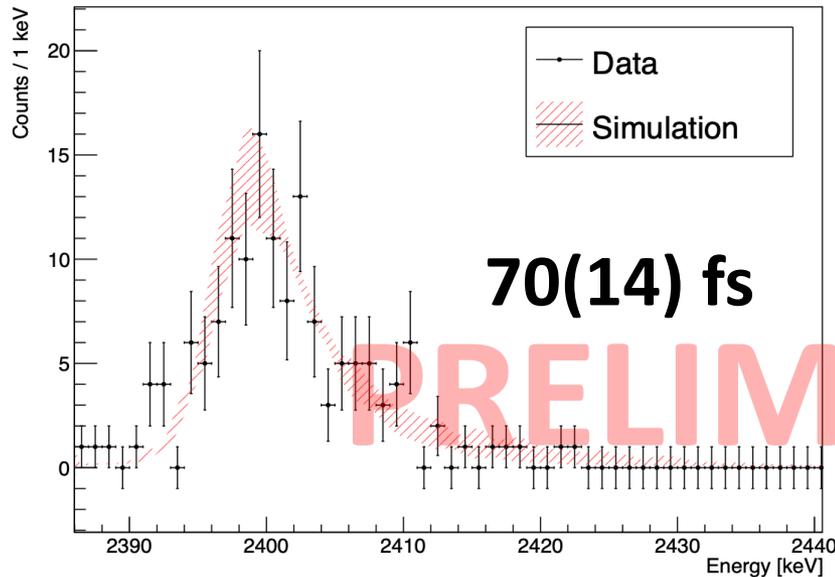


Realistic parameters like angular distributions and resolutions of HPGe detectors are added to the simulation.

The experimental and simulated spectra are compared using the least- $\chi^2$  test.

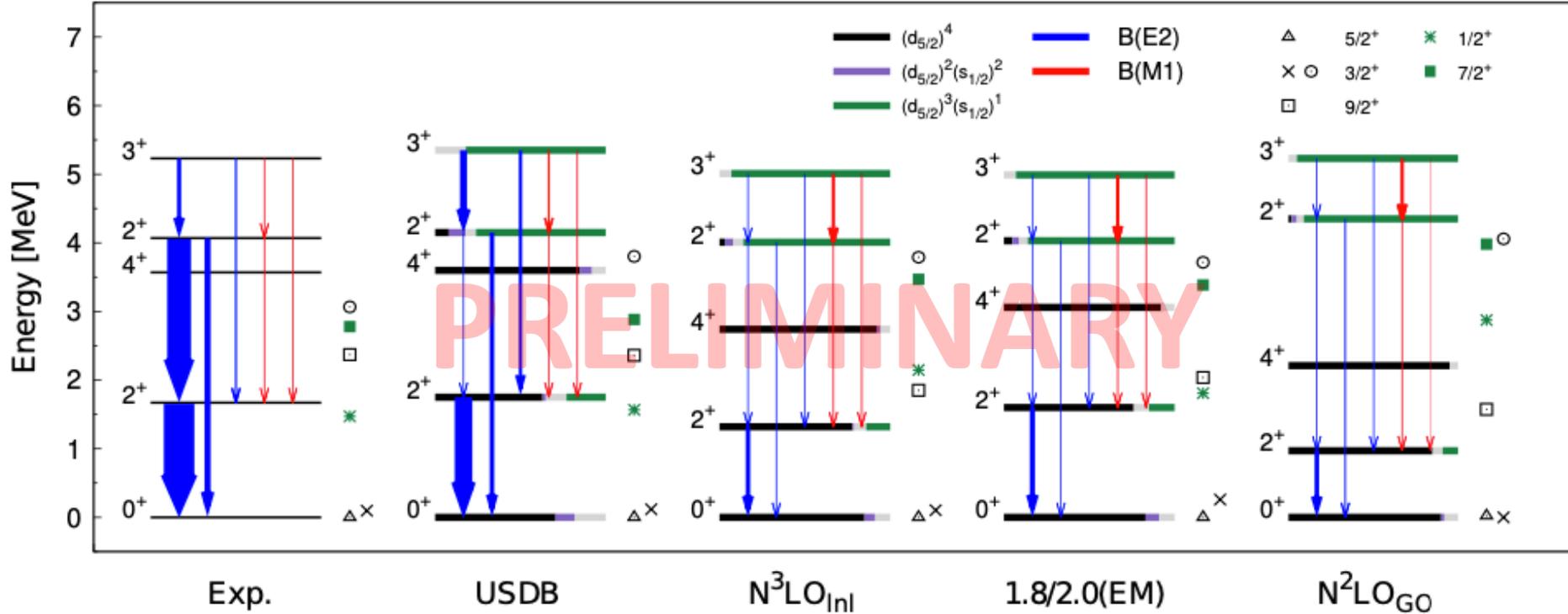
# Lifetime measurements

Statistical errors extracted using the  $\Delta\chi^2=4.6$  corresponding to a 90% confidence level for a 2-dimensional  $\chi^2$  surface.

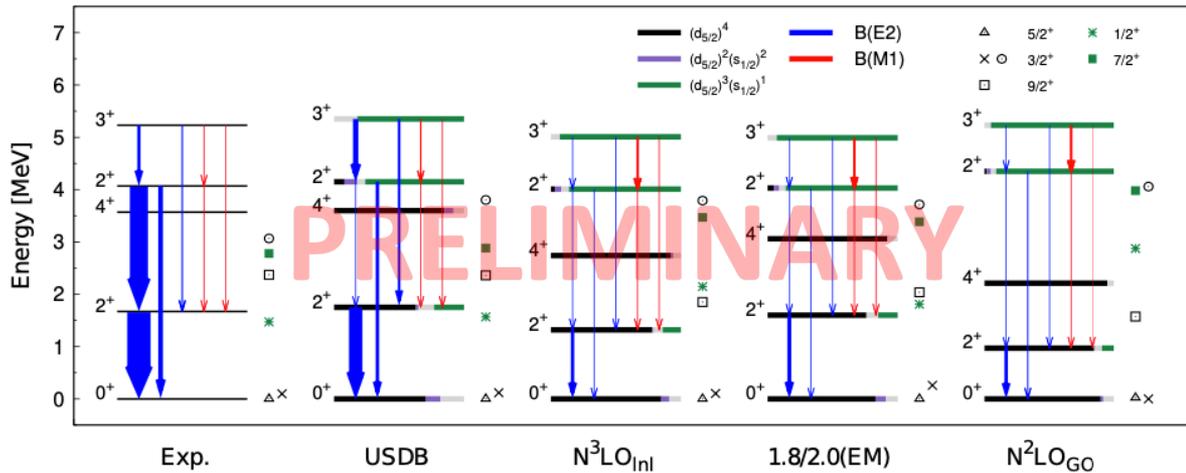


# Comparison with theory

Comparison between experimental reduced transition probabilities and theoretical models: ab-initio VS-IMSRG and USDB



# Comparison with theory



Calculations performed by J. Menéndez and T. Miyagi

Underestimation of  
B(E2)

Role of the B(M1) in  
the comparison

Nature of the  $2^+_{1}$  state  
more complex

# Thanks for the attention

I. Zanon, E. Clément, A. Goasduff, J. Menéndez, T. Miyagi, M. Ciemała, M. Assié, F. Flavigny, C. Fougeres, S. Leblond, A. Lemasson, A. Matta, D. Ramos, K. Rezykina, M. Rejmund, M. Siciliano, D. Ackermann, D. Beaumel, S. Bottoni, D. Brugnara, N. de Sereville, F. Delauney, F. Didierjean, G. De France, P. Delahaye, J. Dudouet, D. Fernández, J.L. Fuentes, A.F. Gadea Raga, F. Galtarossa, V. Girard-Alcindor, F. Hammache, A. Kosoglu, C. Lenain, J. Ljungvall, A. Lopez-Martens, G. Pasqualato, D. Ragueira Castro, J.S. Rojo, A. Uteпов, Y.H. Kim, M. Zielinska

On behalf of the **AGATA**, **VAMOS** and **MUGAST** collaborations

