High-precision spectroscopy of ^{20}O benchmarking ab-initio calculations in light nuclei

Irene Zanon

Post-doctoral Fellow

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Università degli Studi di Ferrara

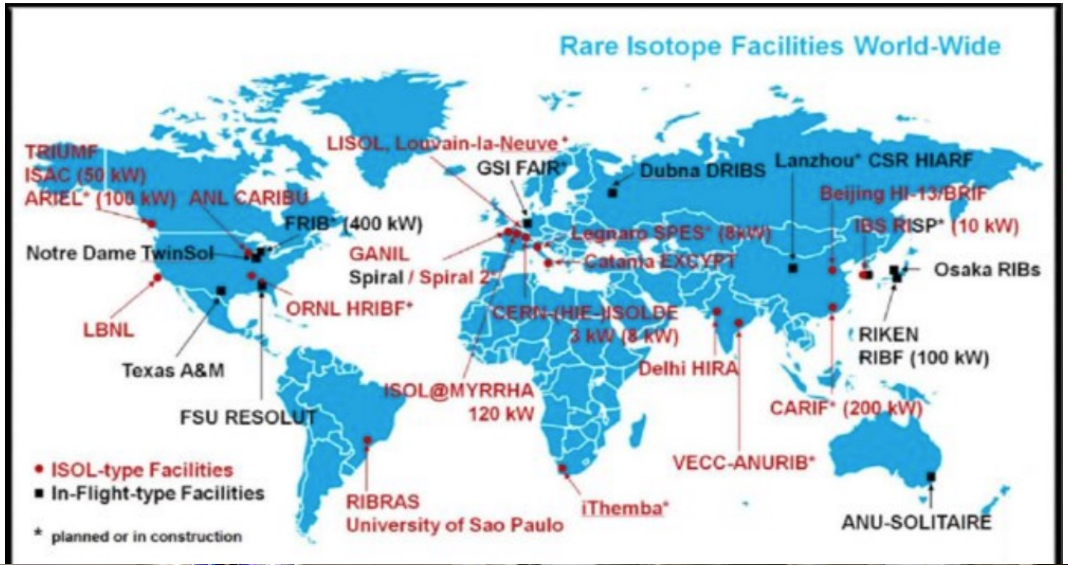
KTH Vetenskap och Konst

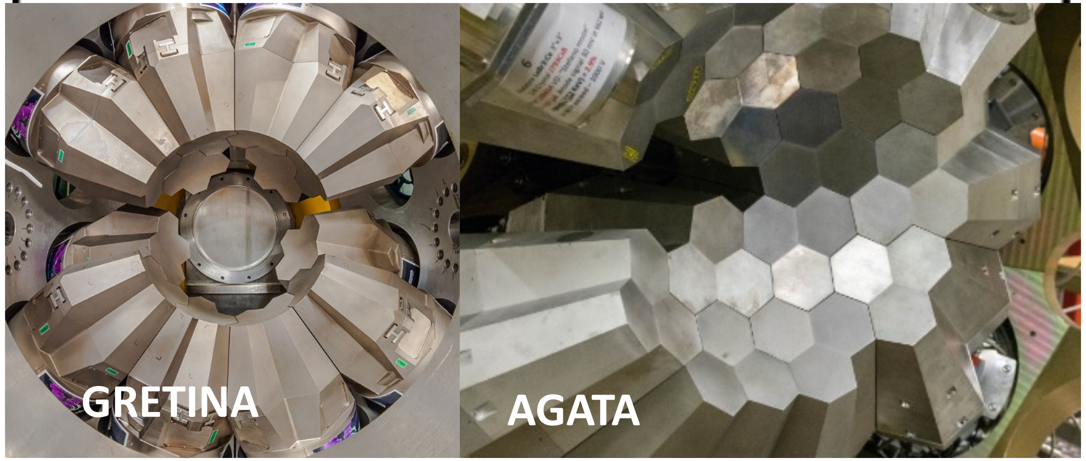
Outlook

- Physical motivations
- The ^{20}O experiment
- γ-particle spectroscopy
- Optimization of the simulation
- Lifetime measurements
- Theoretical interpretation
- Future perspective

Part I:
Physical motivations

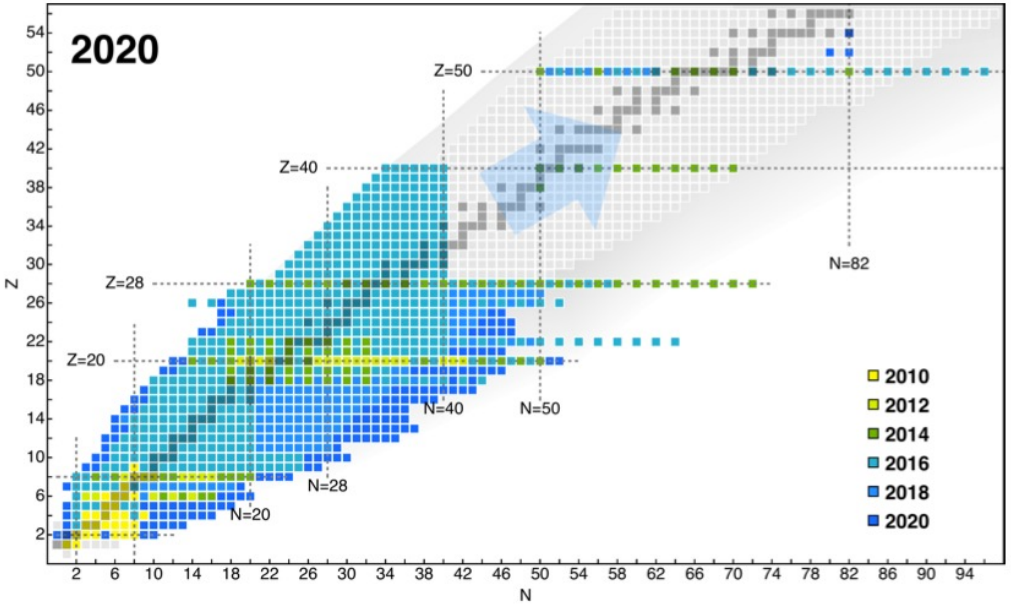
The path until now…



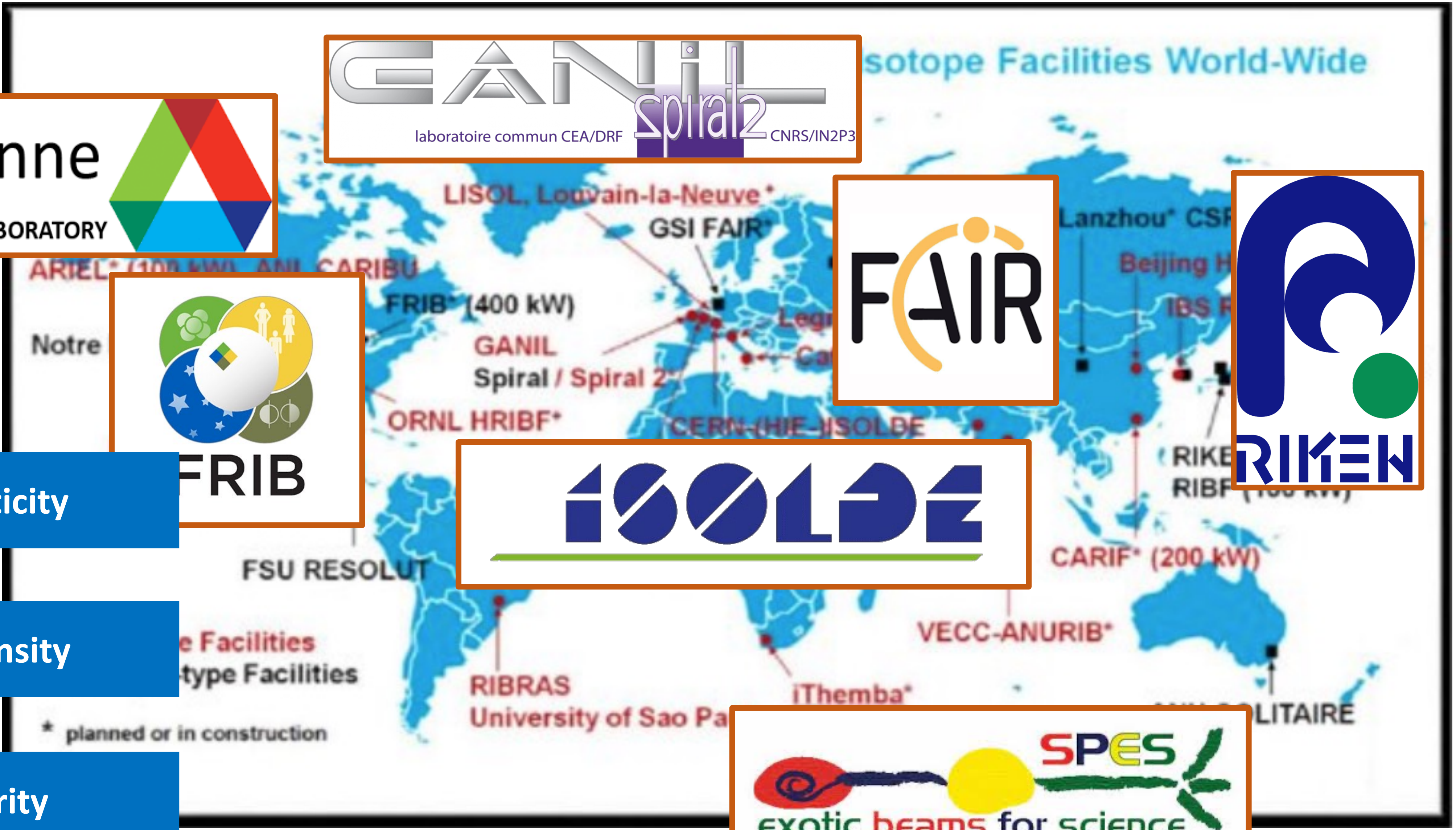


Improvements of experimental setups

Improvements of theoretical models



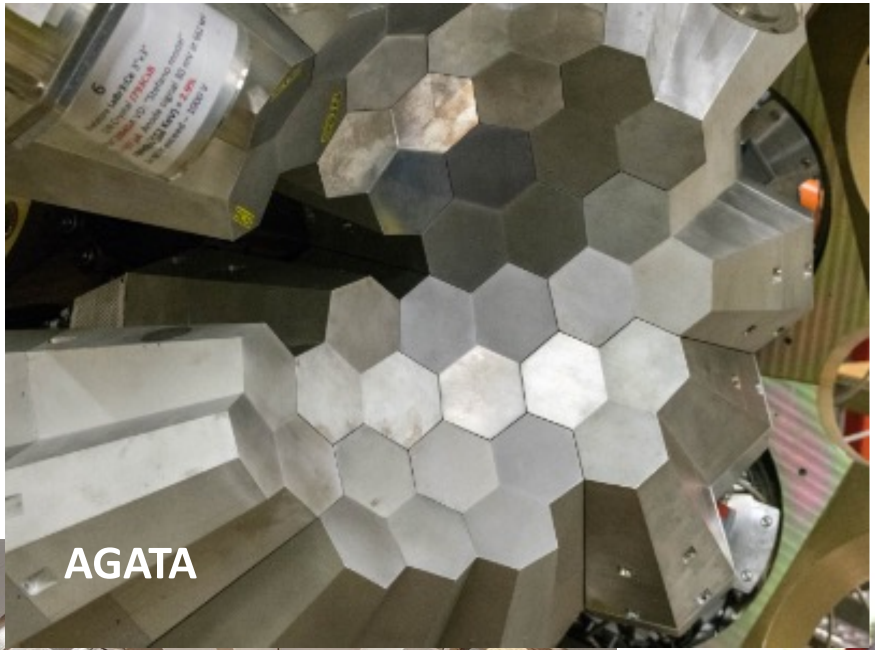
H. Hergert, Front. in Phys. 8 (2020)

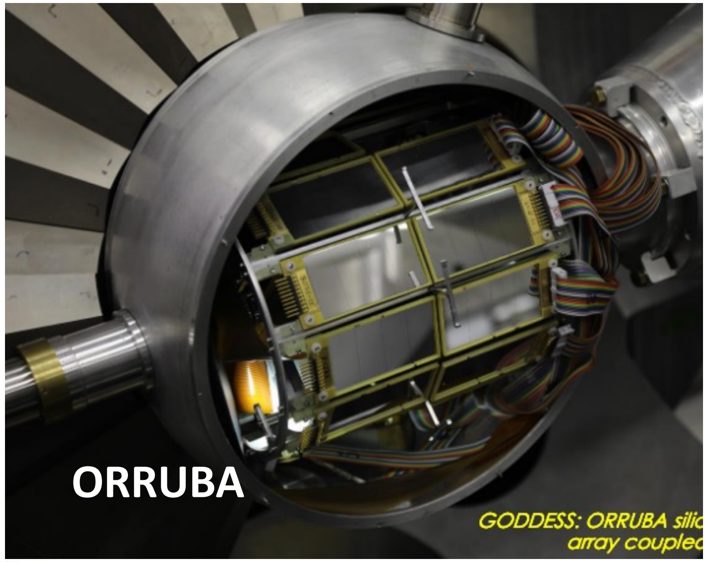


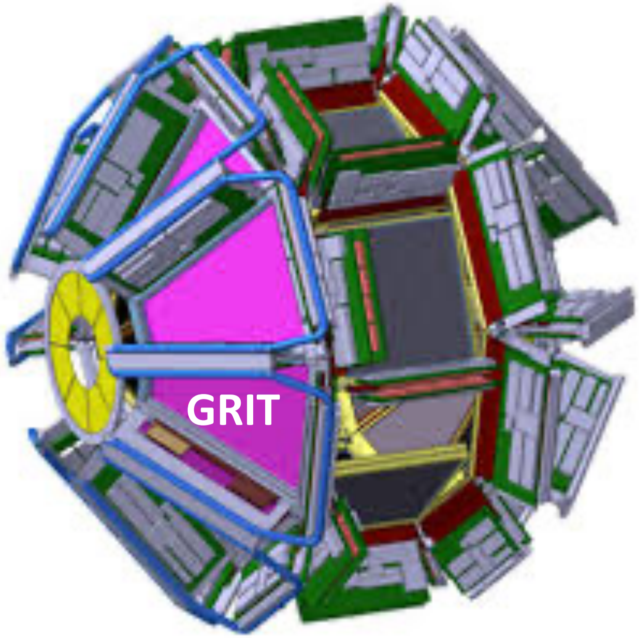
Exoticity

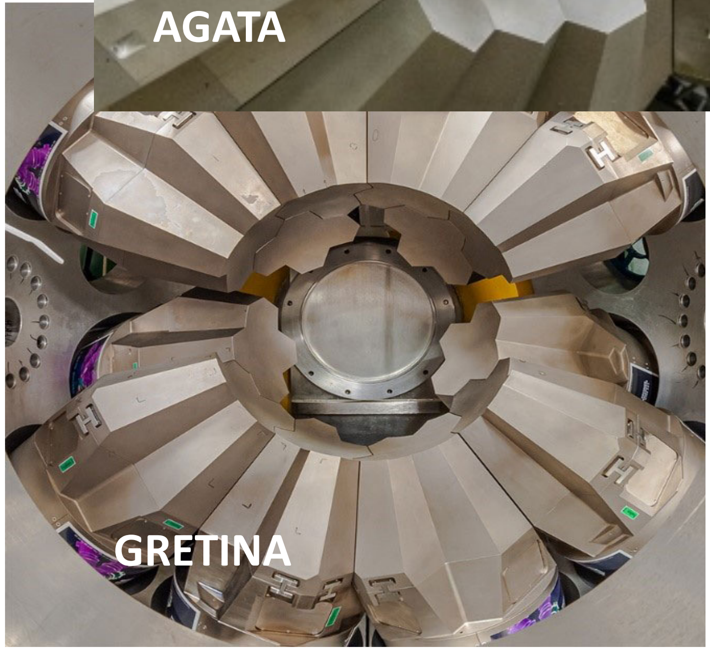
Intensity

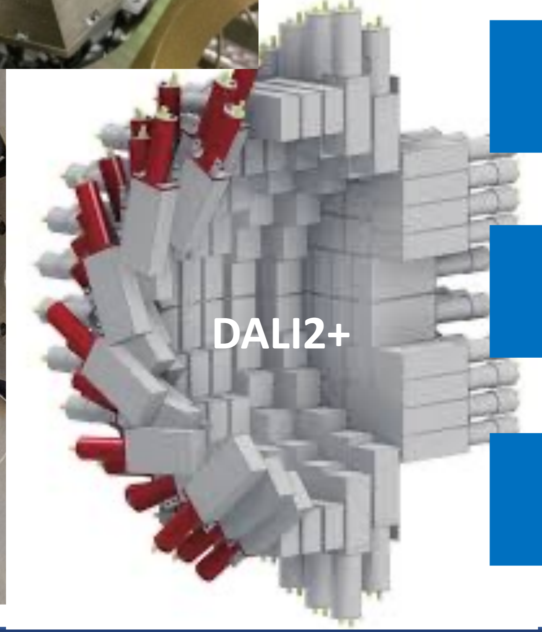
Purity







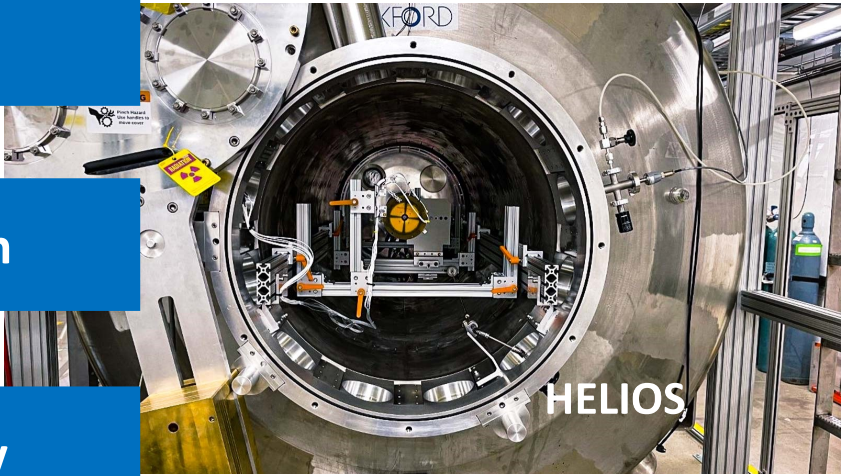


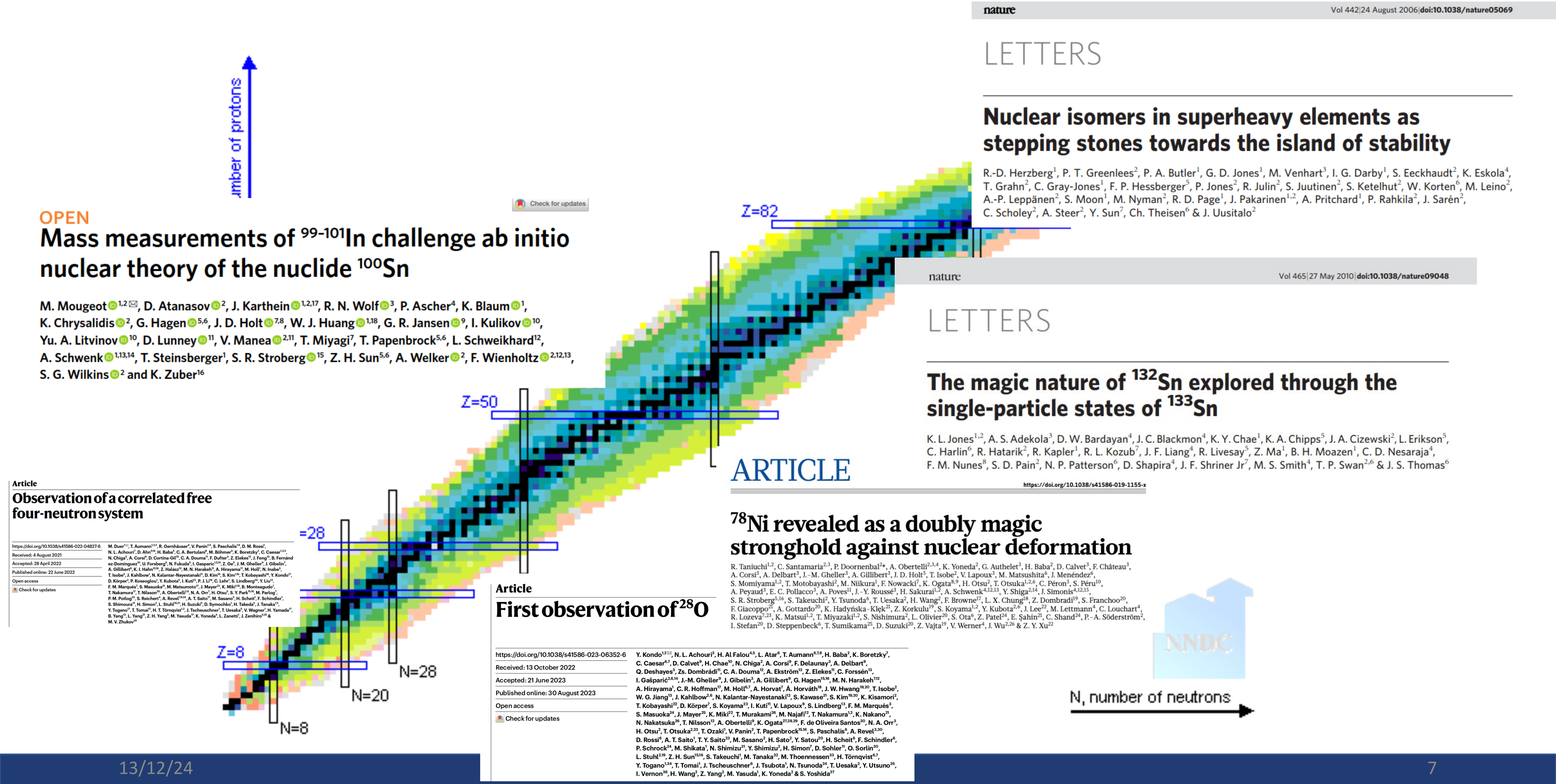


Efficiency

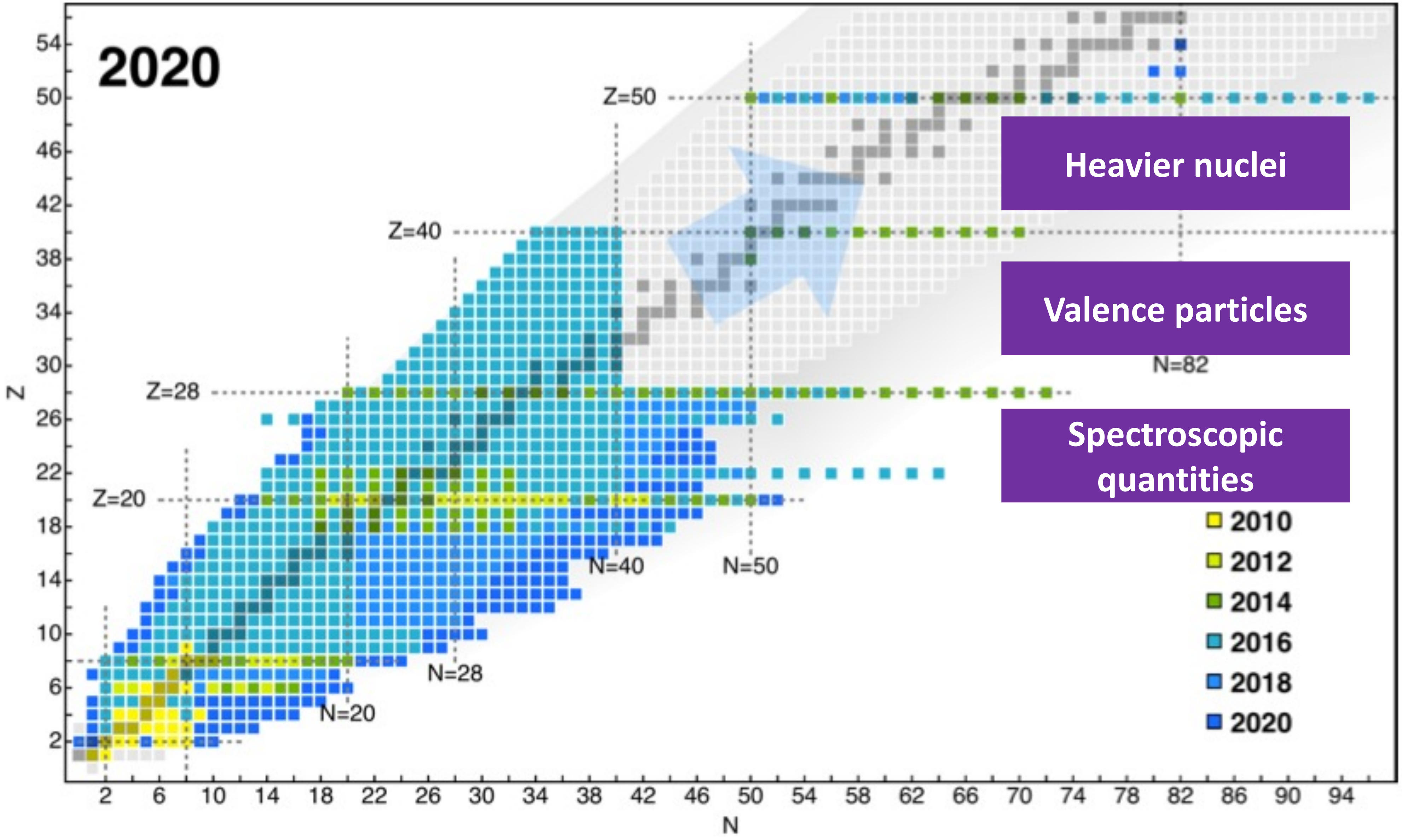
Resolution

Selectivity



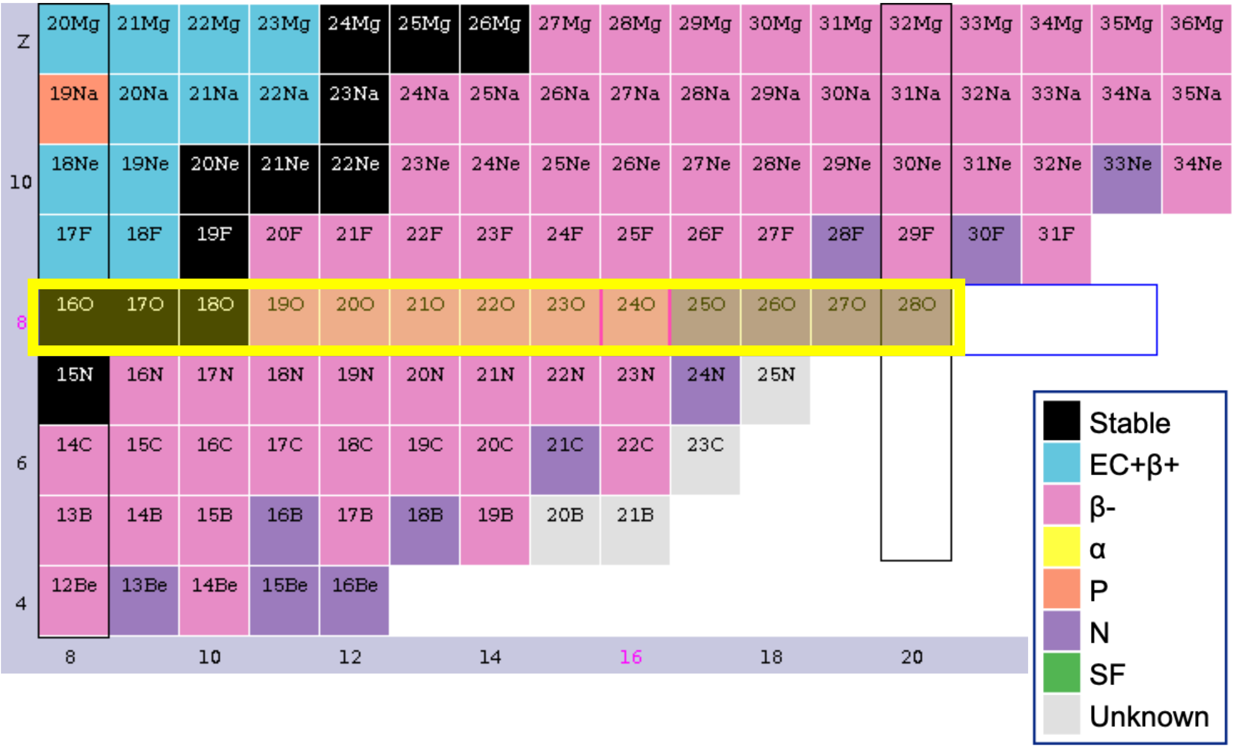


number of protons
Check for updates
OPEN
Mass measurements of 99-101In challenge ab initio nuclear theory of the nuclide 100Sn
M. Mougeot, D. Atanasov, J. Karthein, R. N. Wolf, P. Ascher, K. Blaum, K. Chrysalidis, G. Hagen, J. D. Holt, W. J. Huang, G. R. Jansen, I. Kulikov, Yu. A. Litvinov, D. Lunney, V. Manea, T. Miyagi, T. Papenbrock, L. Schweikhard, A. Schwenk, T. Steinsberger, S. R. Stroberg, Z. H. Sun, A. Welker, F. Wienholtz, S. G. Wilkins and K. Zuber
nature Vol 442|24 August 2006|doi:10.1038/nature05069
LETTERS
Nuclear isomers in superheavy elements as stepping stones towards the island of stability
R.-D. Herzberg, P. T. Greenlees, P. A. Butler, G. D. Jones, M. Venhart, I. G. Darby, S. Eeckhaudt, K. Eskola, T. Grahn, C. Gray-Jones, F. P. Hessberger, P. Jones, R. Julin, S. Juutinen, S. Ketelhut, W. Korten, M. Leino, A.-P. Leppänen, S. Moon, M. Nyman, R. D. Page, J. Pakarinen, A. Pritchard, P. Rahkila, J. Sarén, C. Scholey, A. Steer, Y. Sun, Ch. Theisen & J. Uusitalo
nature Vol 465|27 May 2010|doi:10.1038/nature09048
LETTERS
The magic nature of 132Sn explored through the single-particle states of 133Sn
K. L. Jones, A. S. Adekola, D. W. Bardayan, J. C. Blackmon, K. Y. Chae, K. A. Chipps, J. A. Cizewski, L. Erikson, C. Harlin, R. Hatarik, R. Kapler, R. L. Kozub, J. F. Liang, R. Livesay, Z. Ma, B. H. Moazen, C. D. Nesaraja, F. M. Nunes, S. D. Pain, N. P. Patterson, D. Shapira, J. F. Shriner Jr, M. S. Smith, T. P. Swan & J. S. Thomas
Z=82
Z=50
Z=28
Z=8
N=8
N=20
N=28
Article
Observation of a correlated free four-neutron system
https://doi.org/10.1038/s41586-022-04827-6
Article
First observation of 28O
https://doi.org/10.1038/s41586-023-06352-6
ARTICLE
https://doi.org/10.1038/s41586-019-1155-x
78Ni revealed as a doubly magic stronghold against nuclear deformation
NNDC
N, number of neutrons



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

The «oxygen anomaly»

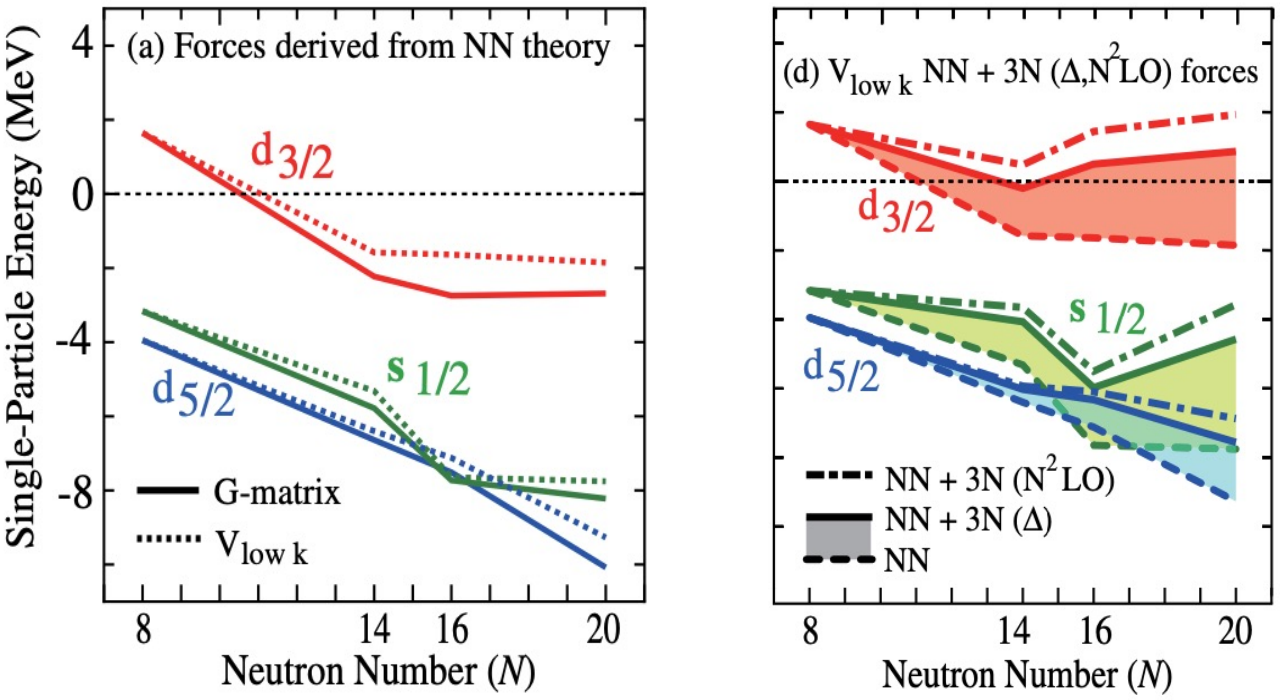


- Disappearance of the N=20 magic number;
- Anomaly in the drip line;

- Nuclei close to the drip-lines are fundamental to understand the nuclear interaction.
- Regular evolution of the drip line in the p-sd region **but** the oxygen represents an exception.
- According to the shell model, ^{28}O is expected to be the heaviest isotope. **^{24}O is observed to be the last bound isotope**.

The oxygen isotopic chain

- The position of the drip line of the oxygen isotopic chain is reproduced by introducing the **3N forces.**
- The location of the drip line changes from the $0d_{3/2}$ orbital (N=20, ^{28}O) to the $1s_{1/2}$ (N=16, ^{24}O).
- Additional information on the relative position of **$1s_{1/2}$ and $0d_{3/2}$ orbitals** is need.



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

PRL 105, 032501 (2010) PHYSICAL REVIEW LETTERS week ending 16 JULY 2010

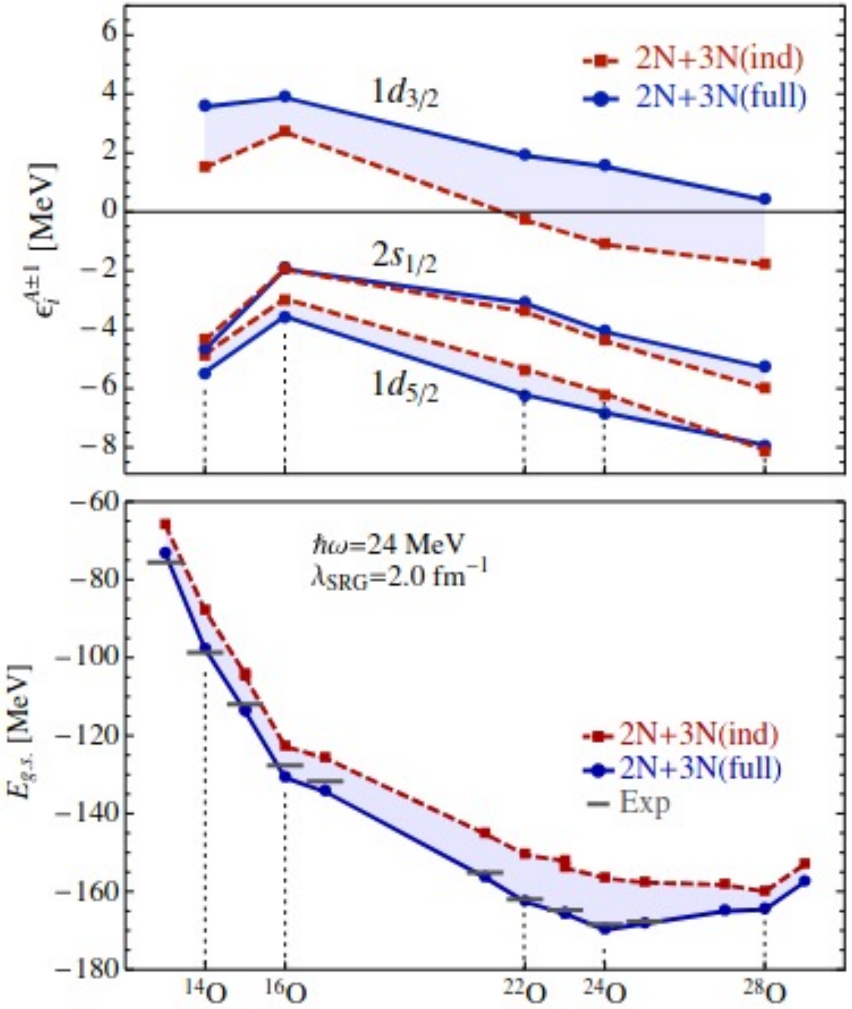
Three-Body Forces and the Limit of Oxygen Isotopes

Takaharu Otsuka,[1,2,3] Toshio Suzuki,[4] Jason D. Holt,[5] Achim Schwenk,[5] and Yoshinori Akaishi[6]
[1]Department of Physics, University of Tokyo, Hongo, Tokyo 113-0033, Japan
[2]Center for Nuclear Study, University of Tokyo, Hongo, Tokyo 113-0033, Japan
[3]National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan, 48824, USA
[4]Department of Physics, College of Humanities and Sciences, Nihon University, Sakurajosui 3, Tokyo 156-8550, Japan
[5]TRIUMF, 4004 Wesbrook Mall, Vancouver, BC, V6T 2A3, Canada
[6]RIKEN Nishina Center, Hirosawa, Wako-shi, Saitama 351-0198, Japan

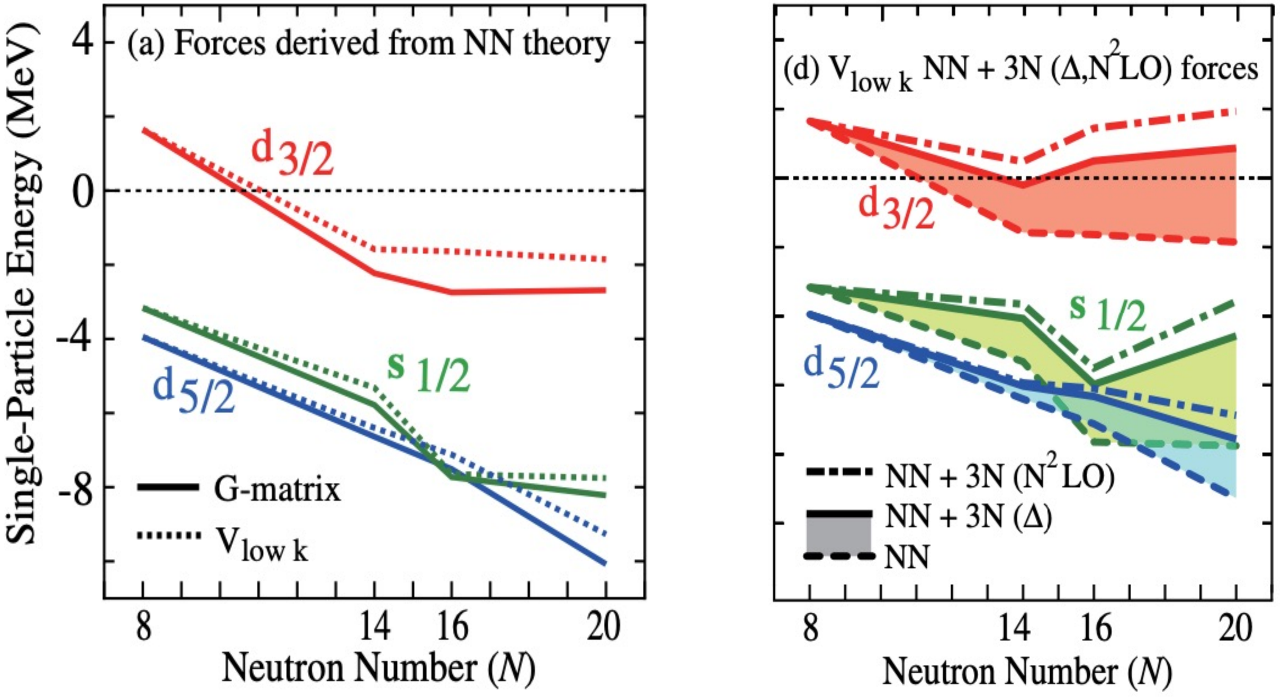
(Received 17 August 2009; published 13 July 2010)

Solution: 3N forces!

The oxygen isotopic chain

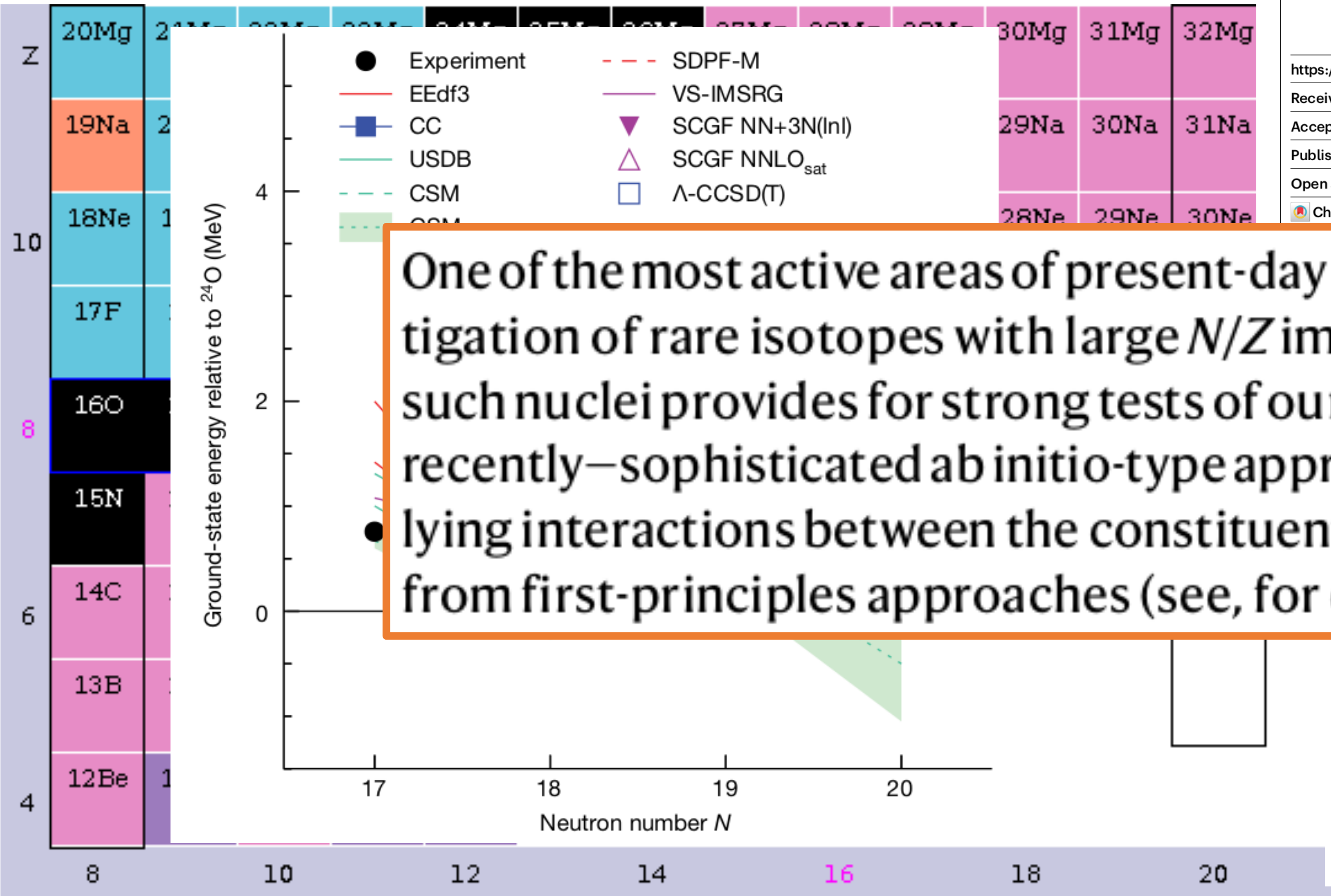


A. Cipollone et al., PRL **111**, 062501 (2013)



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

The oxygen isotopic chain



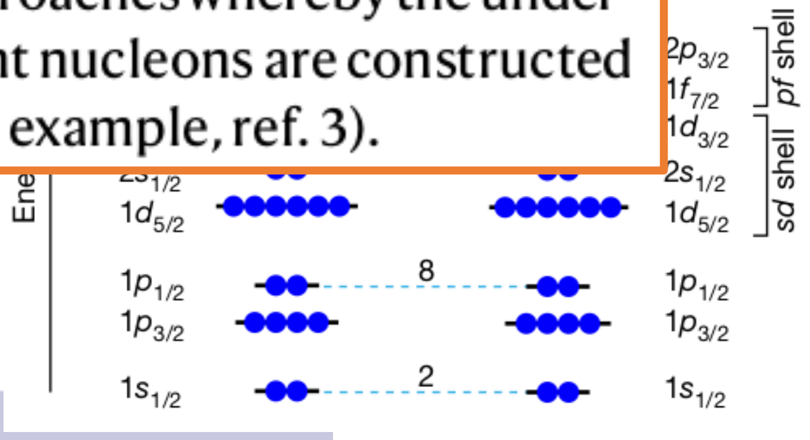
Article

First observation of ^{28}O

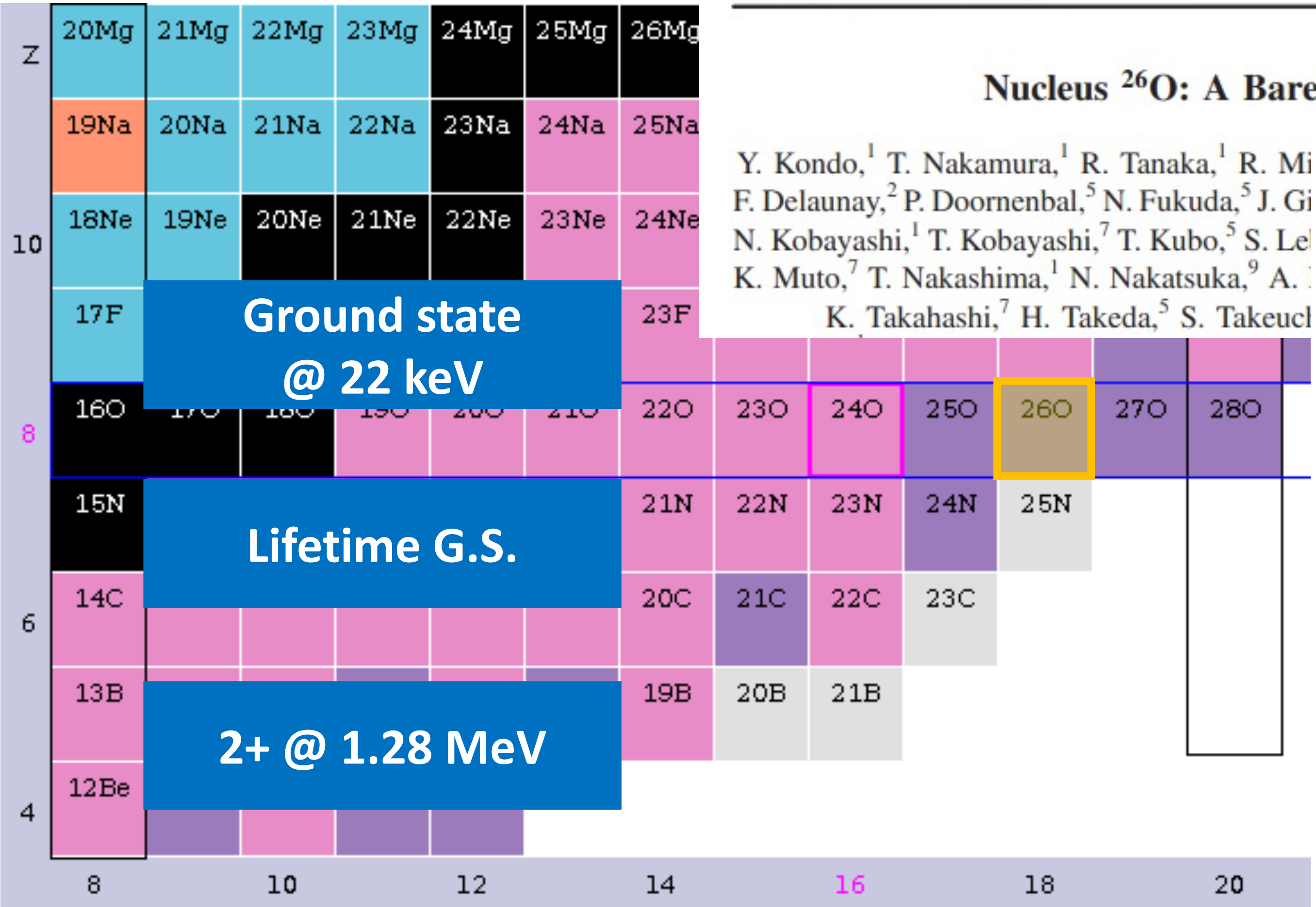
https://doi.org/10.1038/s41586-023-06352-6
Received: 13 October 2022
Accepted: 21 June 2023
Published online: 30 August 2023
Open access
Check for updates

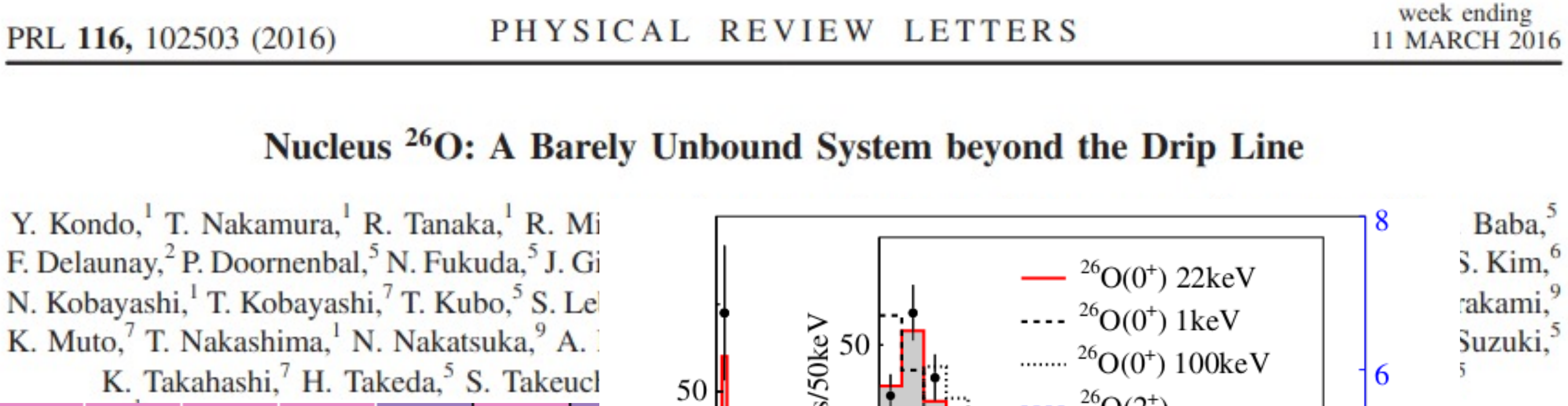
Y. Kondo[1,2] ✉, N. L. Achouri[3], H. Al Falou[4,5], L. Atar[6], T. Aumann[6,7,8], H. Baba[2], K. Boretzky[7], C. Caesar[6,7], D. Calvet[9], H. Chae[10], N. Chiga[2], A. Corsi[9], F. Delaunay[3], A. Delbart[9], Q. Deshayes[3], Zs. Dombrádi[11], C. A. Douma[12], A. Ekström[13], Z. Elekes[11], C. Forssén[13], I. Gašparić[2,6,14], J.-M. Gheller[9], J. Gibelin[3], A. Gillibert[9], G. Hagen[15,16], M. N. Harakeh[7,12], A. Hirayama[1], C. R. Hoffman[17], M. Holl[6,7], A. Horvat[7], Á. Horváth[18], J. W. Hwang[19,20], T. Isobe[2], W. G. Jiang[13], J. Kahlbow[2,6], N. Kalantar-Nayestanaki[12], S. Kawase[21], S. Kim[19,20], K. Kisamori[2], T. Kobayashi[22], D. Körper[7], S. Koyama[23], I. Kuti[11], V. Lapoux[9], S. Lindberg[13], F. M. Marqués[3], S. Masuoka[24], J. Mayer[25], K. Miki[22], T. Murakami[26], M. Najafi[12], T. Nakamura[1,2], K. Nakano[21], N. Nakatsuka[26], T. Nilsson[13], A. Obertelli[9], K. Ogata[27,28,29], F. de Oliveira Santos[30], N. A. Orr[3],
k[15,16], S. Paschalis[6], A. Revel[3,30],
Y. Satou[20], H. Scheit[6], F. Schindler[6],
imon[7], D. Sohler[11], O. Sorlin[30],
oennessen[33], H. Törnqvist[6,7],
Tsunoda[24], T. Uesaka[2], Y. Utsuno[35],
& S. Yoshida[37]

> One of the most active areas of present-day nuclear physics is the investigation of rare isotopes with large N/Z imbalances. The structure of such nuclei provides for strong tests of our theories, including—most recently—sophisticated ab initio-type approaches whereby the underlying interactions between the constituent nucleons are constructed from first-principles approaches (see, for example, ref. 3).



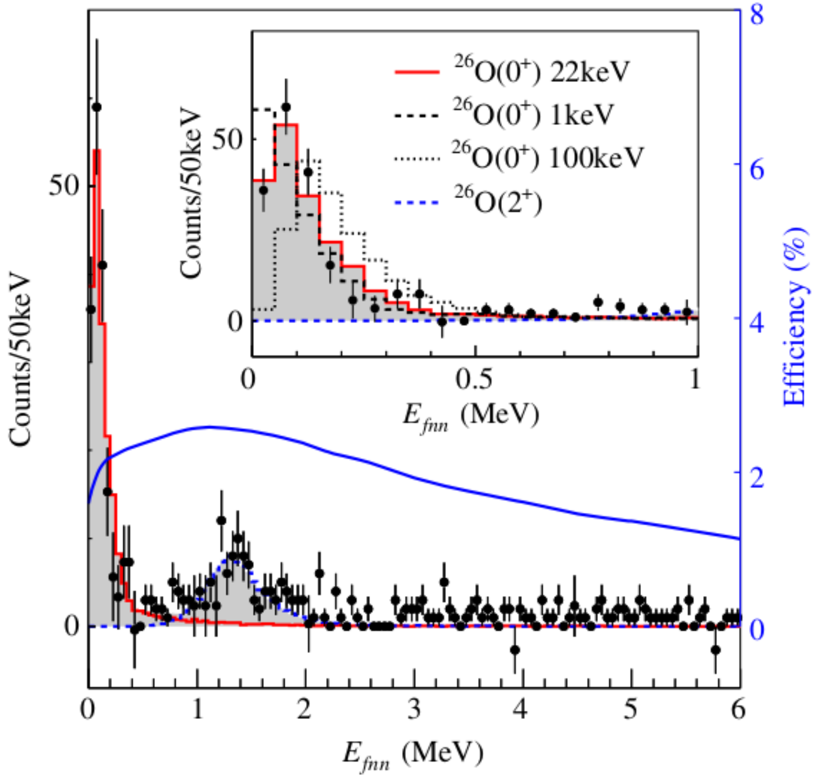
The oxygen isotopic chain



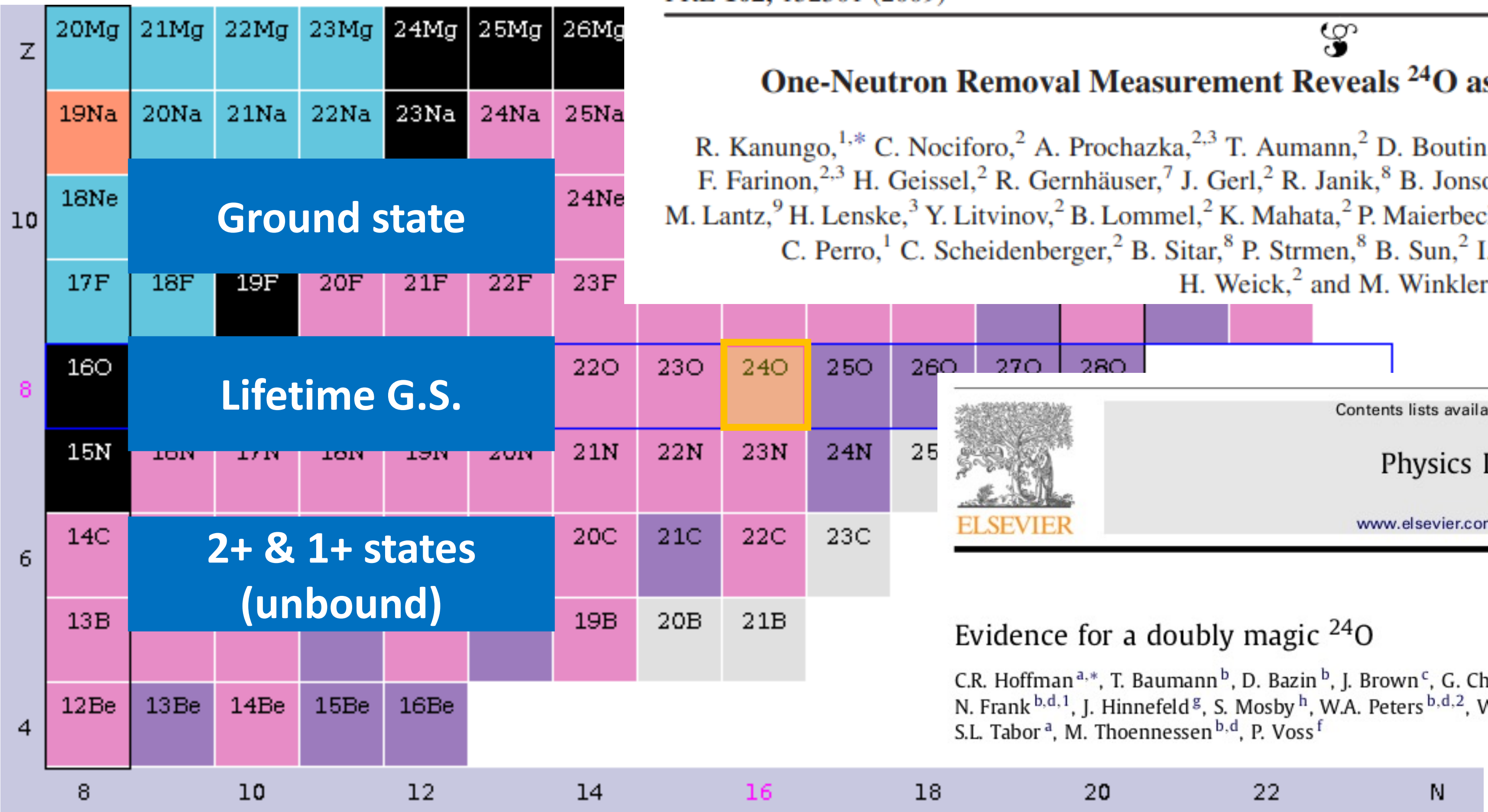

PRL 116, 102503 (2016) PHYSICAL REVIEW LETTERS week ending 11 MARCH 2016

Nucleus ^{26}O: A Barely Unbound System beyond the Drip Line

Y. Kondo,[1] T. Nakamura,[1] R. Tanaka,[1] R. Mi ... Baba,[5]
F. Delaunay,[2] P. Doornenbal,[5] N. Fukuda,[5] J. Gi ... S. Kim,[6]
N. Kobayashi,[1] T. Kobayashi,[7] T. Kubo,[5] S. Le ... akami,[9]
K. Muto,[7] T. Nakashima,[1] N. Nakatsuka,[9] A. ... Suzuki,[5]
K. Takahashi,[7] H. Takeda,[5] S. Takeuc ...



The oxygen isotopic chain



PRL **102,** 152501 (2009) PHYSICAL REVIEW LETTERS week ending 17 APRIL 2009

One-Neutron Removal Measurement Reveals ^{24}O as a New Doubly Magic Nucleus

R. Kanungo,[1,*] C. Nociforo,[2] A. Prochazka,[2,3] T. Aumann,[2] D. Boutin,[3] D. Cortina-Gil,[4] B. Davids,[5] M. Diakaki,[6] F. Farinon,[2,3] H. Geissel,[2] R. Gernhäuser,[7] J. Gerl,[2] R. Janik,[8] B. Jonson,[9] B. Kindler,[2] R. Knöbel,[2,3] R. Krücken,[7] M. Lantz,[9] H. Lenske,[3] Y. Litvinov,[2] B. Lommel,[2] K. Mahata,[2] P. Maierbeck,[7] A. Musumarra,[10,11] T. Nilsson,[9] T. Otsuka,[12] C. Perro,[1] C. Scheidenberger,[2] B. Sitar,[8] P. Strmen,[8] B. Sun,[2] I. Szarka,[8] I. Tanihata,[13] Y. Utsuno,[14] H. Weick,[2] and M. Winkler[2]

Contents lists available at ScienceDirect

Physics Letters B

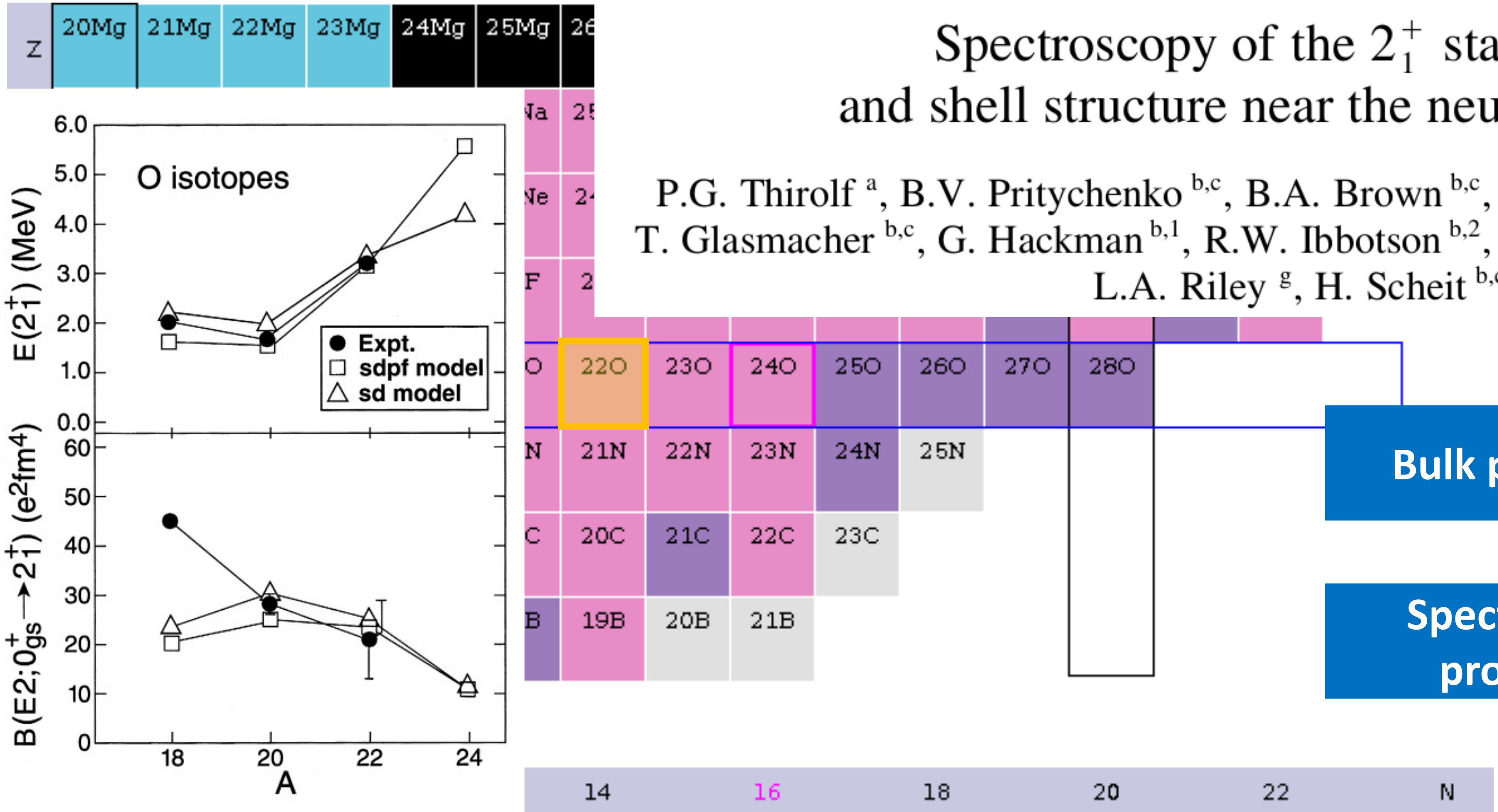
www.elsevier.com/locate/physletb

ELSEVIER

Evidence for a doubly magic ^{24}O

C.R. Hoffman[a,*], T. Baumann[b], D. Bazin[b], J. Brown[c], G. Christian[b,d], D.H. Denby[e], P.A. DeYoung[e], J.E. Finck[f], N. Frank[b,d,1], J. Hinnefeld[g], S. Mosby[h], W.A. Peters[b,d,2], W.F. Rogers[h], A. Schiller[b,3], A. Spyrou[b], M.J. Scott[f], S.L. Tabor[a], M. Thoennessen[b,d], P. Voss[f]

The oxygen isotopic chain



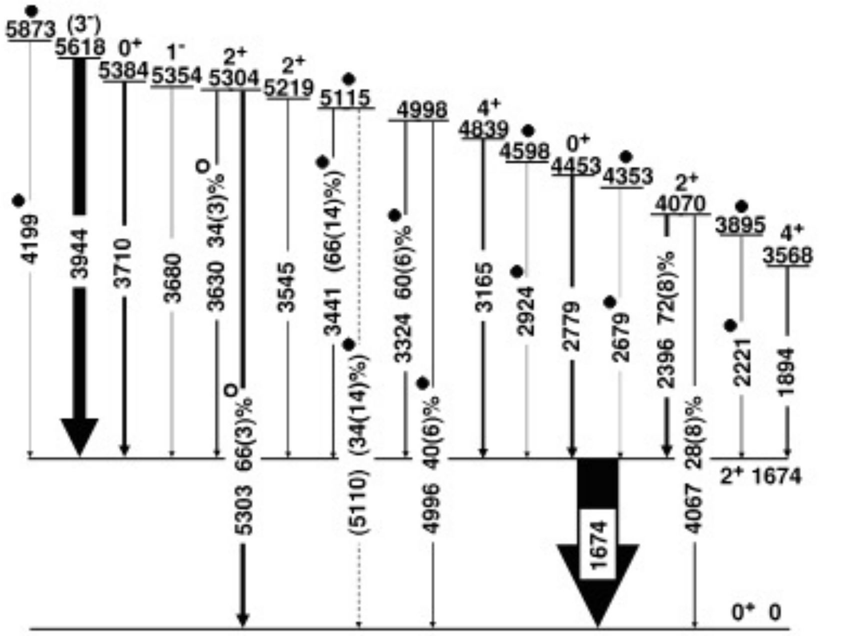
Spectroscopy of the 2_1^+ state in ^{22}O
and shell structure near the neutron drip line

P.G. Thirolf [a], B.V. Pritychenko [b,c], B.A. Brown [b,c], P.D. Cottle [d], M. Chromik [a], T. Glasmacher [b,c], G. Hackman [b,1], R.W. Ibbotson [b,2], K.W. Kemper [d], T. Otsuka [e,f], L.A. Riley [g], H. Scheit [b,c,3]

Bulk properties

Spectroscopic properties

cha



Testing *ab initio* nuclear structure in neutron-rich nuclei: Lifetime measurements of second 2^+ state in ^{16}C and ^{20}O

M. Ciemała,[1,*] S. Ziliani,[2,3] F. C. L. Crespi,[2,3] S. Leoni,[2,3,†] B. Fornal,[1,‡] A. Maj,[1] P. Bednarczyk,[1] G. Benzoni,[3] A. Bracco,[2,3] C. Boiano,[3] S. Bottoni,[2,3] S. Brambilla,[3] M. Bast,[4] M. Beckers,[4] T. Braunroth,[4] F. Camera,[2,3] N. Cieplicka-Oryńczak,[1] E. Clément,[5] S. Coelli,[3] O. Dorvaux,[6] S. Erturk,[7] G. de France,[5] C. Fransen,[4] A. Goldkuhle,[4] J. Grębosz,[1] M. N. Harakeh,[8] Ł. W. Iskra,[1,3] B. Jacquot,[5] A. Karpov,[9] M. Kicińska-Habior,[10] Y. Kim,[5] M. Kmiecik,[1] A. Lemasson,[5] S. M. Lenzi,[11,12] M. Lewitowicz,[5] H. Li,[5] I. Matea,[13] K. Mazurek,[1] C. Michelagnoli,[14] M. Matejska-Minda,[15,1] B. Million,[3] C. Müller-Gatermann,[4] V. Nanal,[16] P. Napiorkowski,[15] D. R. Napoli,[17] R. Palit,[16] M. Rejmund,[5] Ch. Schmitt,[6] M. Stanoiu,[18] I. Stefan,[13] E. Vardaci,[19] B. Wasilewska,[1] O. Wieland,[3] M. Zieblinski,[1] M. Zielińska,[20] A. Ataç,[21] D. Barrientos,[22] B. Birkenbach,[4] A. J. Boston,[23] B. Cederwall,[21] L. Charles,[6] J. Collado,[24] D. M. Cullen,[25] P. Désesquelles,[26] C. Domingo-Pardo,[27] J. Dudouet,[28] J. Eberth,[4] V. González,[24] J. Goupil,[5] L. J. Harkness-Brennan,[23] H. Hess,[4] D. S. Judson,[23] A. Jungclaus,[29] W. Korten,[20] M. Labiche,[30] A. Lefevre,[5] R. Menegazzo,[11] D. Mengoni,[11,12] J. Nyberg,[31] R. M. Perez-Vidal,[27] Zs. Podolyak,[32] A. Pullia,[2,3] F. Recchia,[11,12] P. Reiter,[4] F. Saillant,[5] M. D. Salsac,[20] E. Sanchis,[24] O. Stezowski,[28] Ch. Theisen,[20] J. J. Valiente-Dobón,[17] J. D. Holt,[33,34] J. Menéndez,[35,36] A. Schwenk,[37,38,39] and J. Simonis[40]

PHYSICAL REVIEW C **85**, 054318 (2012)

Experimental study of the ^{19}O$(d,p)^{20}$O reaction in inverse kinematics

C. R. Hoffman,[1,*] B. B. Back,[1] B. P. Kay,[1,†] J. P. Schiffer,[1] M. Alcorta,[1] S. I. Baker,[1] S. Bedoor,[2] P. F. Bertone,[1] J. A. Clark,[1] C. M. Deibel,[1,3,‡] B. DiGiovine,[1] S. J. Freeman,[4] J. P. Greene,[1] J. C. Lighthall,[1,2] S. T. Marley,[1,2] R. C. Pardo,[1] K. E. Rehm,[1] A. Rojas,[5,§] D. Santiago-Gonzalez,[5] D. K. Sharp,[4] D. V. Shetty,[2] J. S. Thomas,[4] I. Wiedenhöver,[5] and A. H. Wuosmaa[2]

[1]*Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA*

Department, Western Michigan University, Kalamazoo, Michigan 49008, USA

Nuclear Astrophysics, Michigan State University, East Lansing, Michigan 48824, USA

s and Astronomy, University of Manchester, Manchester M13 9PL, United Kingdom

ment of Physics, Florida State University, Tallahassee, Florida 32306, USA

(Received 23 January 2012; published 29 May 2012)

PRL **94,** 132501 (2005) PHYSICAL REVIEW LETTERS week ending 8 APRIL 2005

***p-sd* Shell Gap Reduction in Neutron-Rich Systems and Cross-Shell Excitations in ^{20}O**

M. Wiedeking, S. L. Tabor, J. Pavan, A. Volya, A. L. Aguilar, I. J. Calderin, D. B. Campbell, W. T. Cluff, E. Diffenderfer, J. Fridmann, C. R. Hoffman, K. W. Kemper, S. Lee, M. A. Riley, B. T. Roeder, C. Teal, V. Tripathi, and I. Wiedenhöver

Florida State University, Tallahassee, Florida 32306, USA

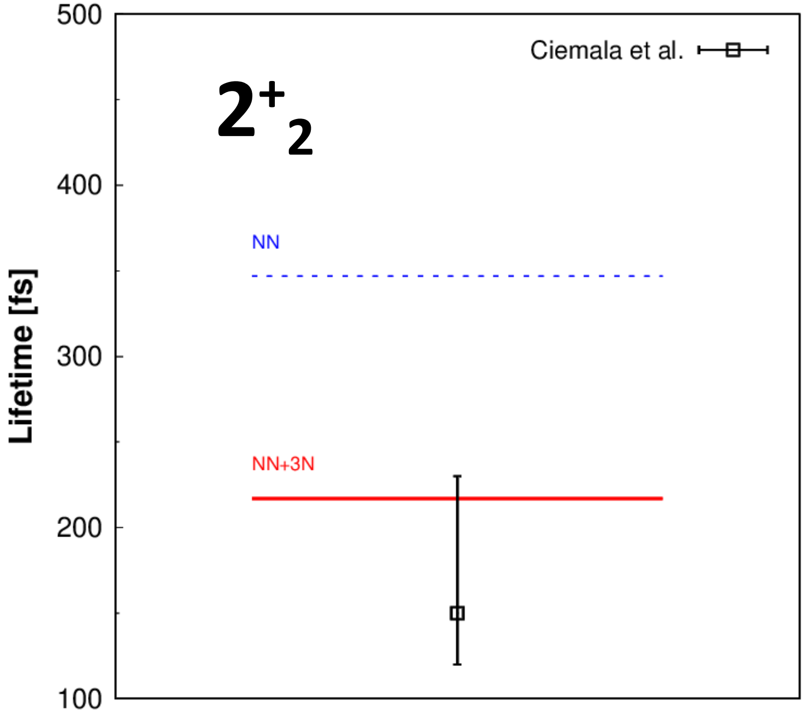
(Received 13 December 2004; published 7 April 2005)

22	N

The ^{20}O studycase

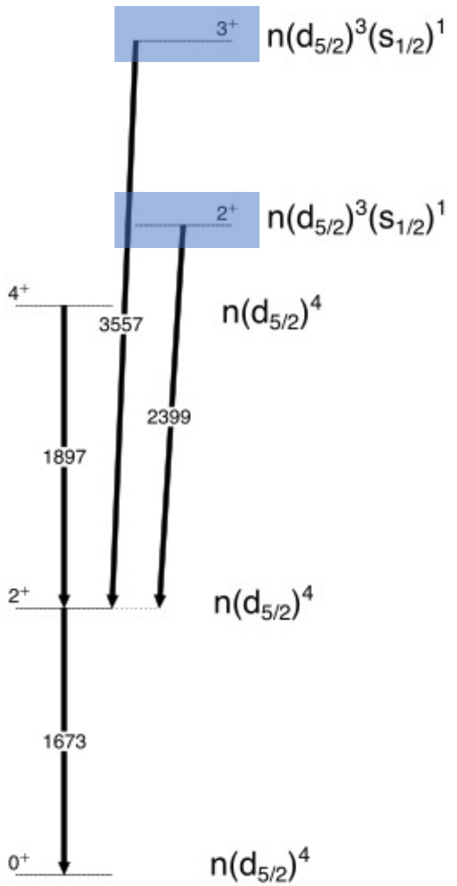
- In ^{20}O, the 2^+_2 and 3^+_1 states are based on a mixed configuration of $d_{5/2}$ and $s_{1/2}$;
- The positions of the the orbitals influences the lifetime of the 2^+_2 and 3^+_1 states of ^{20}O.

- Precise particle-gamma spectroscopy;
- Measure 2^+_2 and 3^+_1 states;
- Comparison with theory



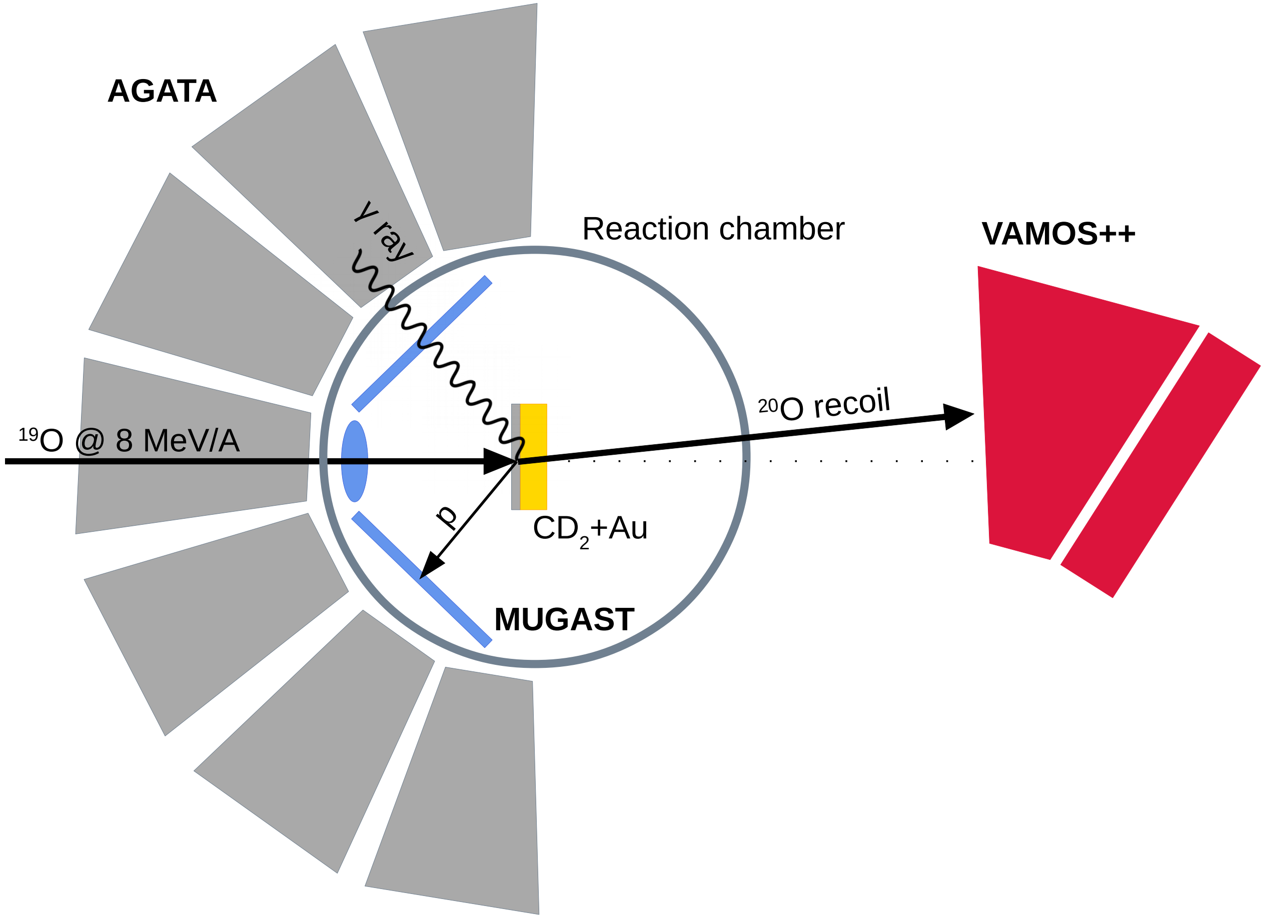
*M. Ciemała et al, PRC **101** 021303 (2020)*

^{20}O



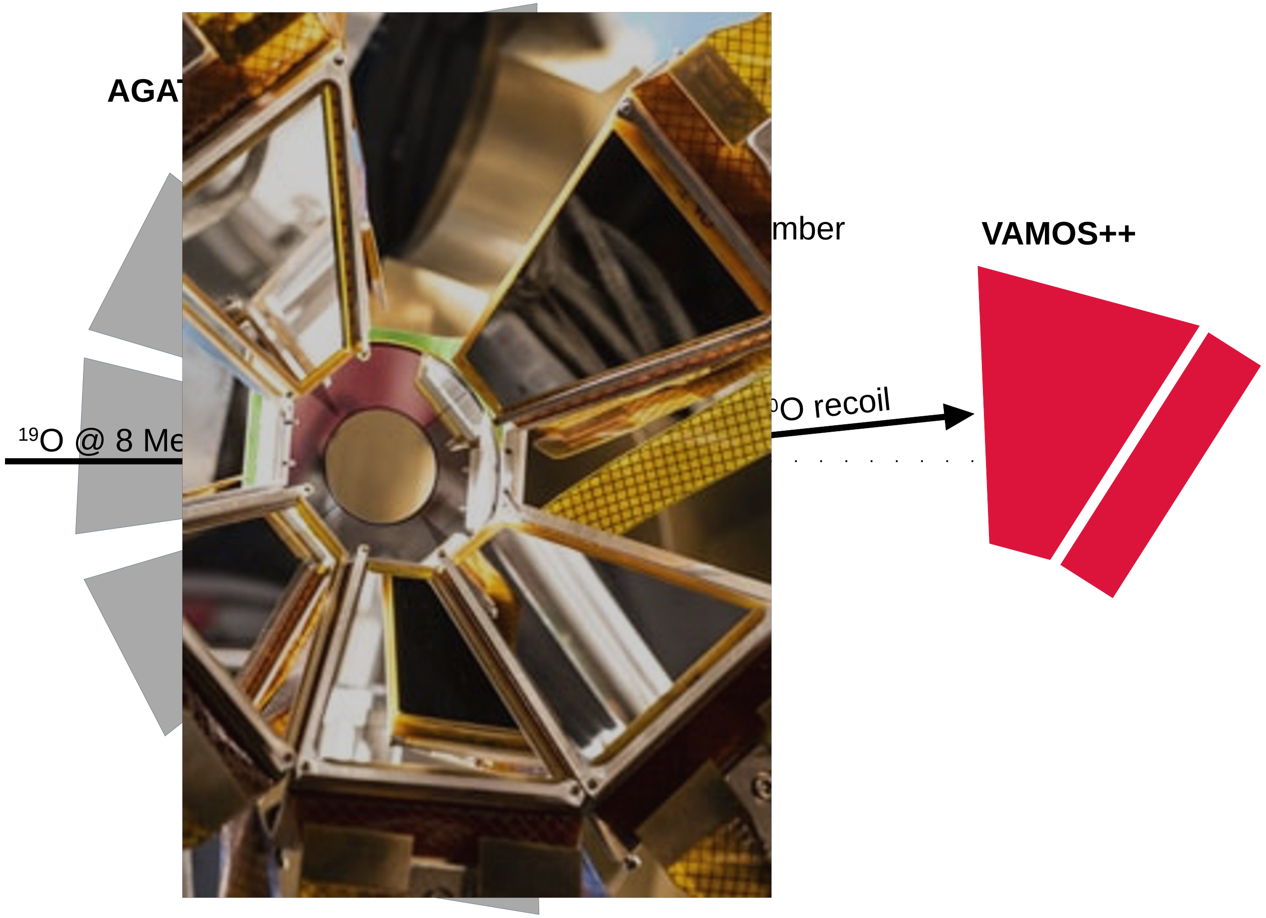
Part II:
The experiment

The experiment



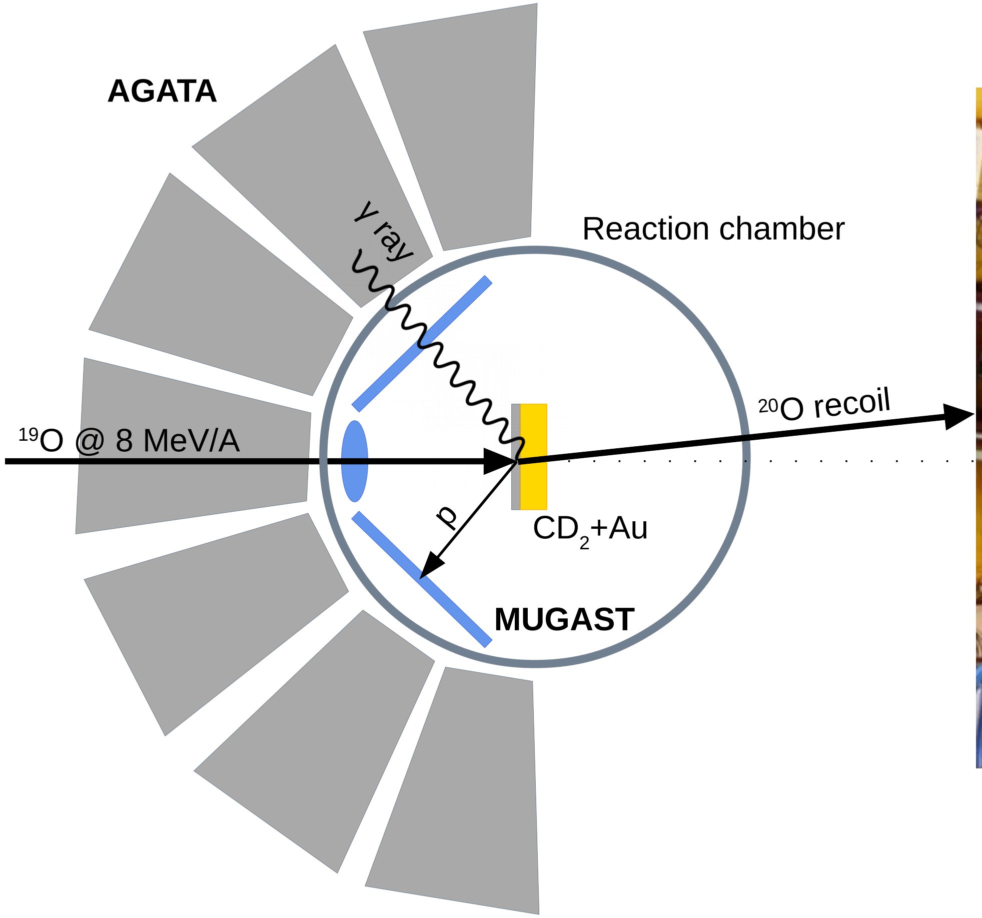
- Performed in GANIL (France) in 2020
- $^{19}O(d,p)^{20}O$ reaction;
- RIB of ^{19}O @8 MeV/A
  i: $4x10^5$ pps, purity > 99%;
- Target CD_2 0.3 mg/cm^2
  + ^{nat}Au 20 mg/cm^2;
- AGATA array + MUGAST + VAMOS.

The experiment: MUGAST



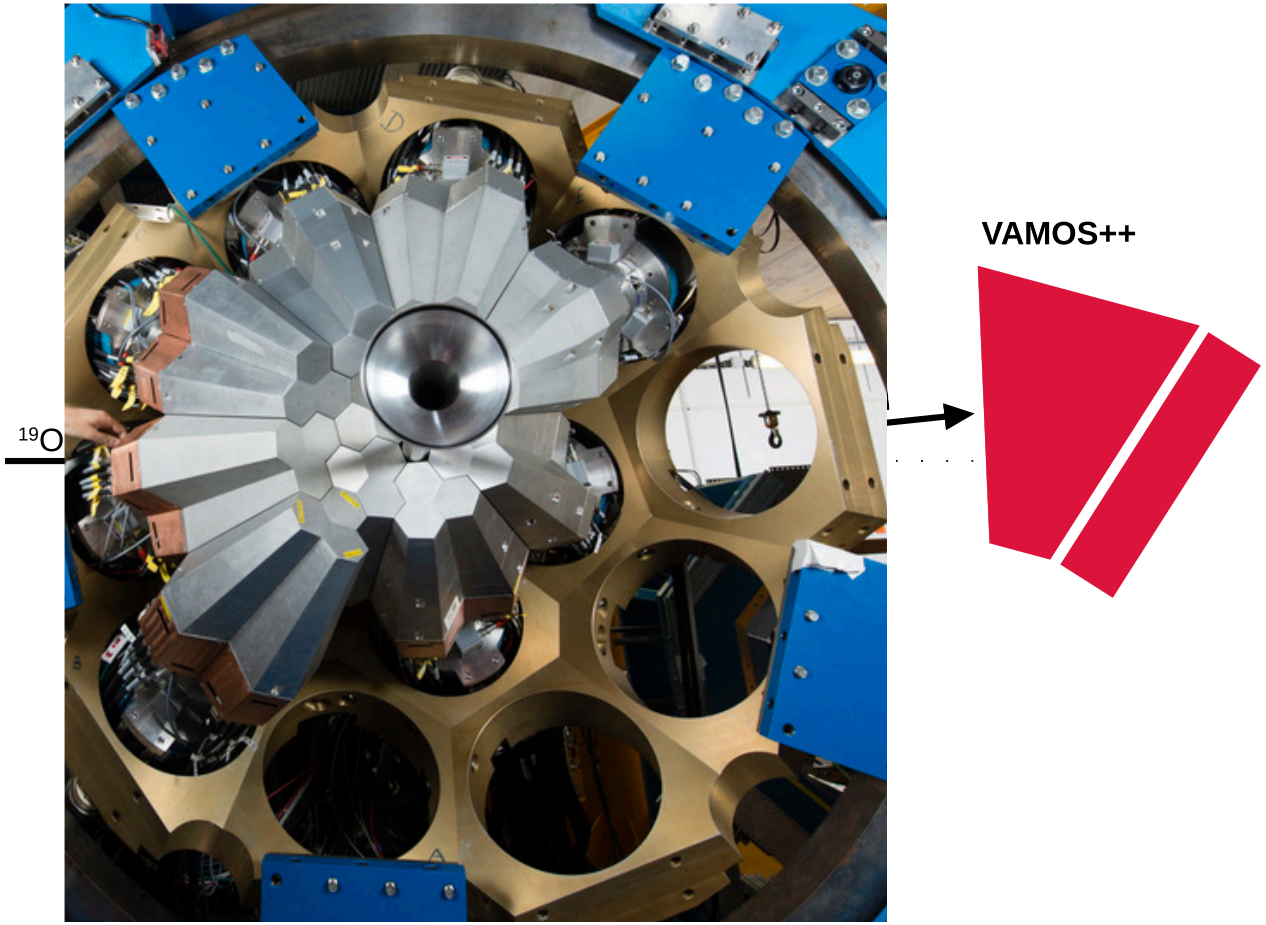
- Array of silicon detectors;
- Detection of light charged particles;
- 7 trapezoids + 1 annular;
- Designed to be coupled to AGATA;
- Segmentation of the silicons;
- Good energy and angular resolution.

The experiment: VAMOS++



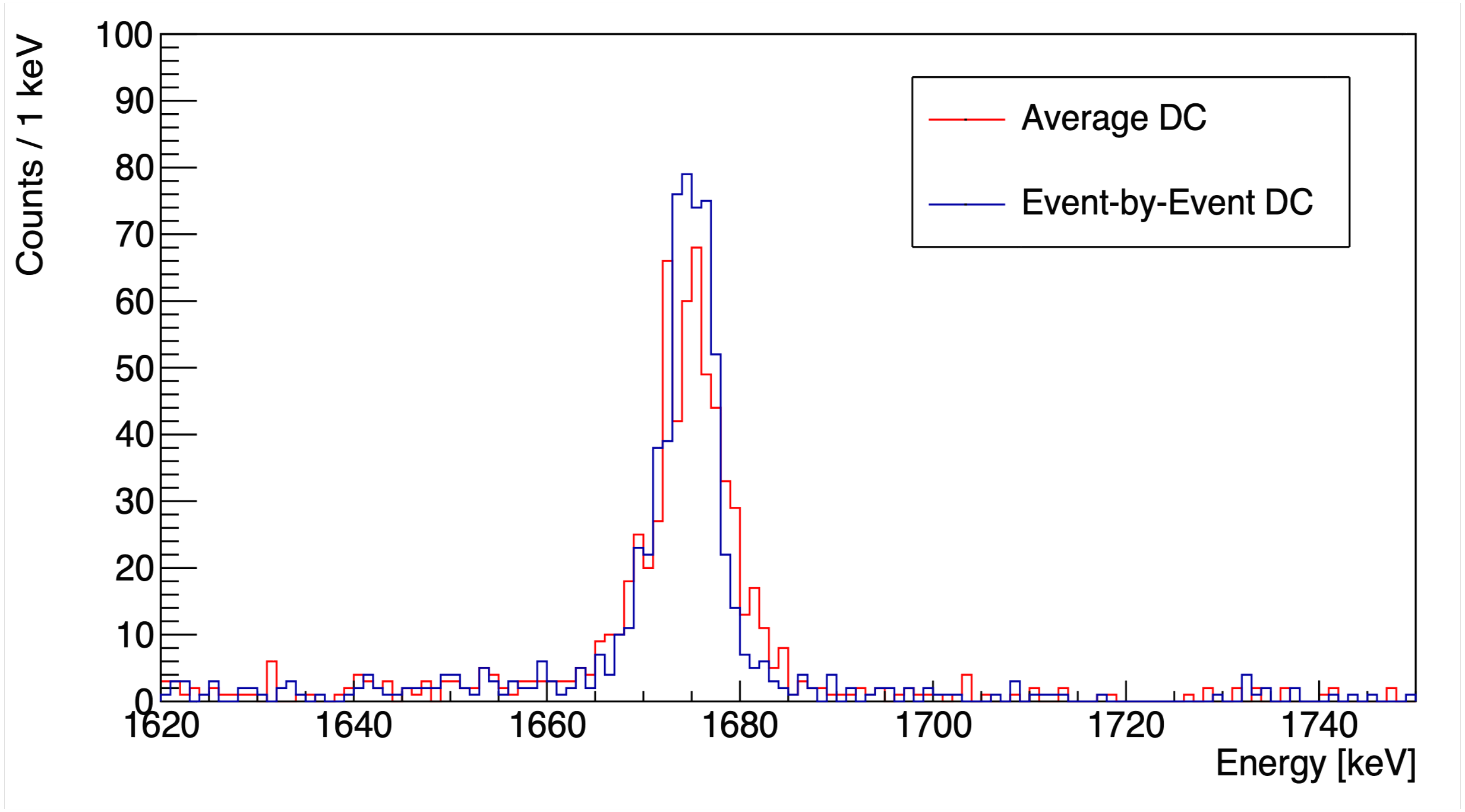
- Magnetic spectrometer;
- Identification of the channel of interest.

The experiment: AGATA



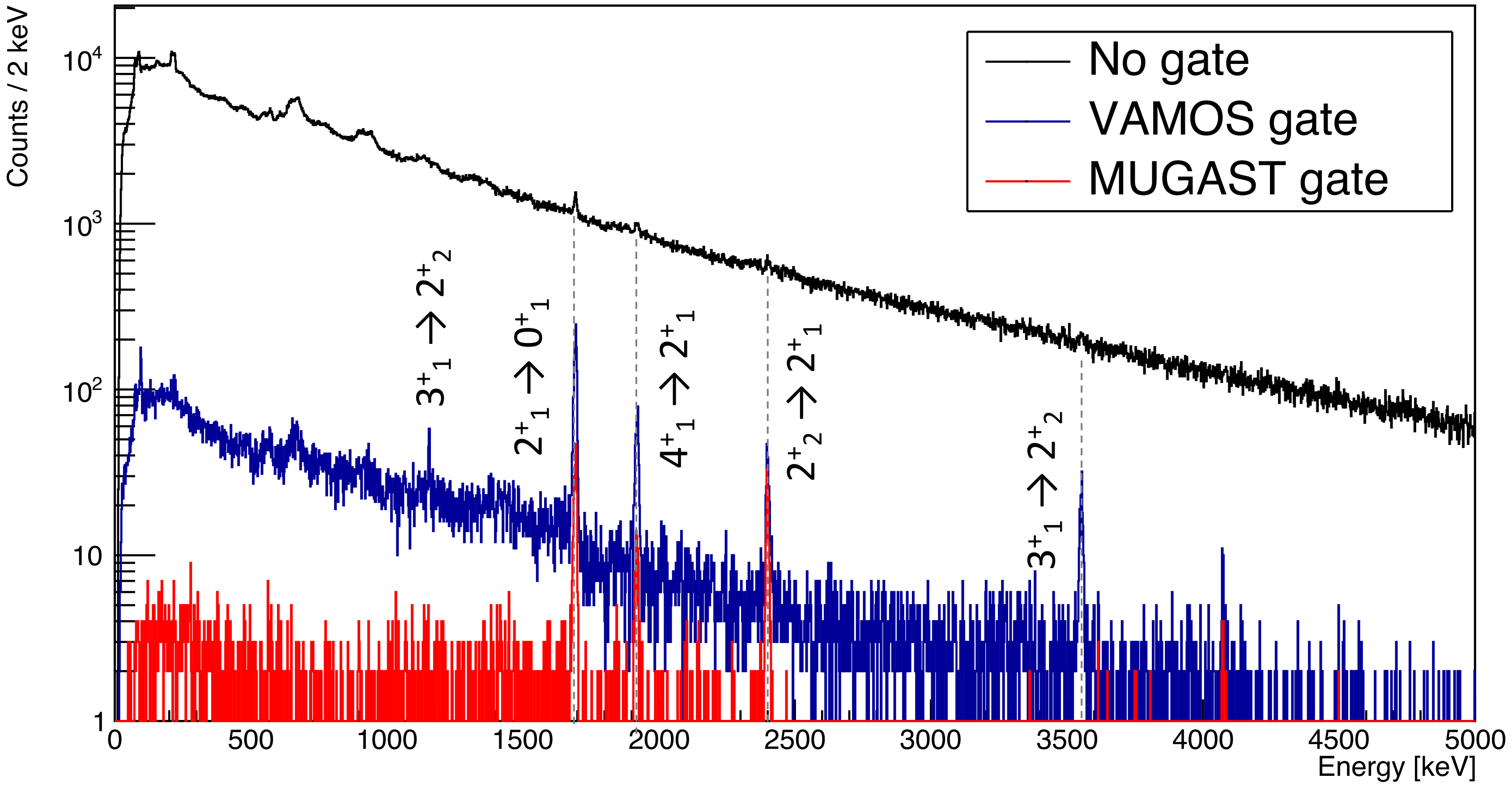
- State-of-the-art of gamma-ray array.
- 36 HPGe crystals;
- 36 segments per crystal + 1 core;
- Combination of PSA and tracking;

Event-by-event Doppler Correction



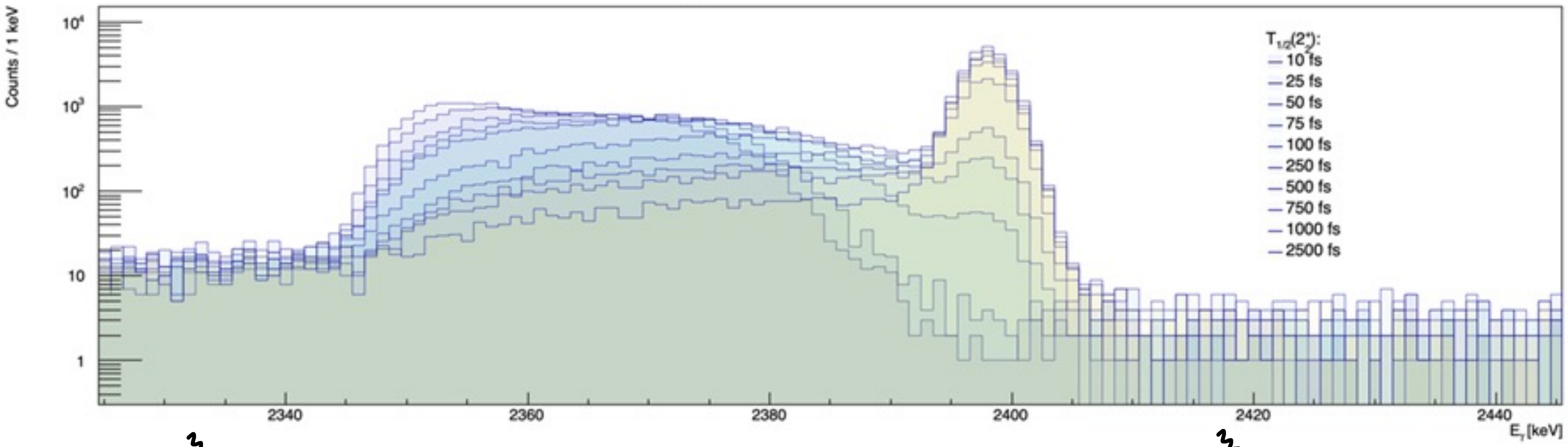
- Detection of the proton;
- Kinematic reconstruction;
- Improved the resolution of 25% with respect to the one using the average β=12.6%

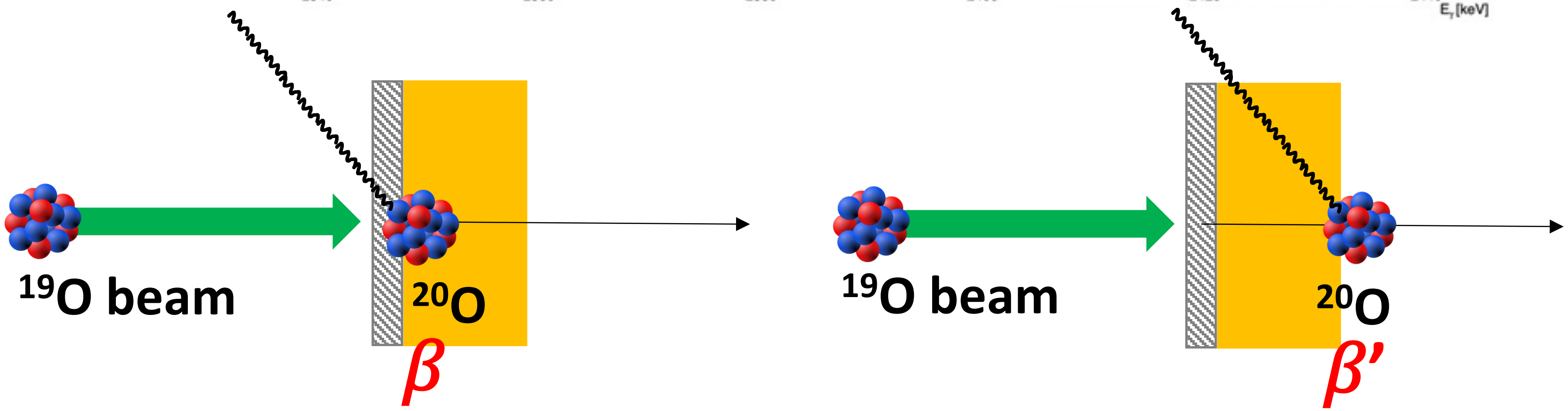
Selectivity of the set-up



- Low beam intensity;
- AGATA triggerless;
- Different gates to reduce the background.

The Doppler-Shift Attenuation Method



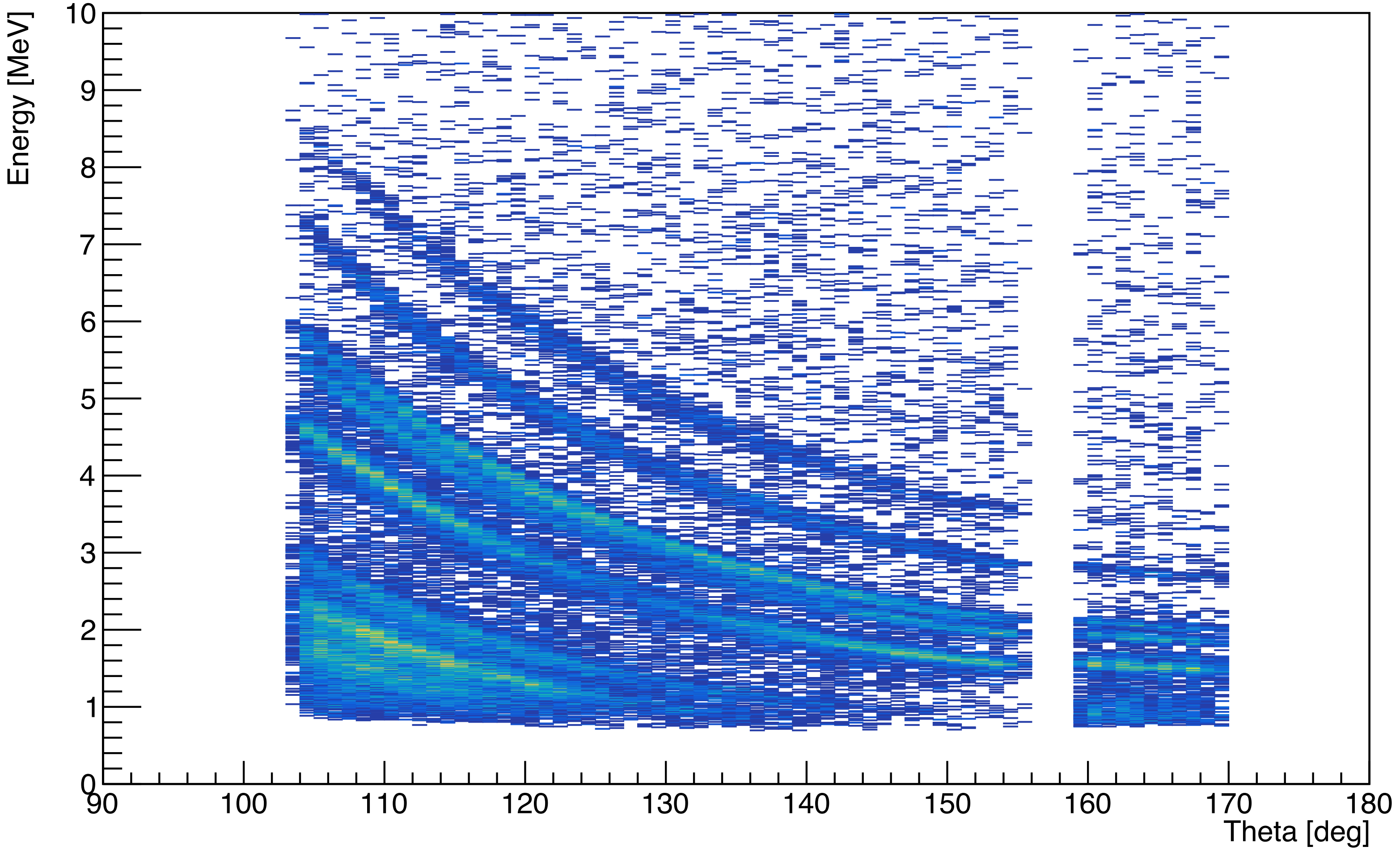


- Optimization of the degrader;
- Resolution of AGATA and MUGAST;

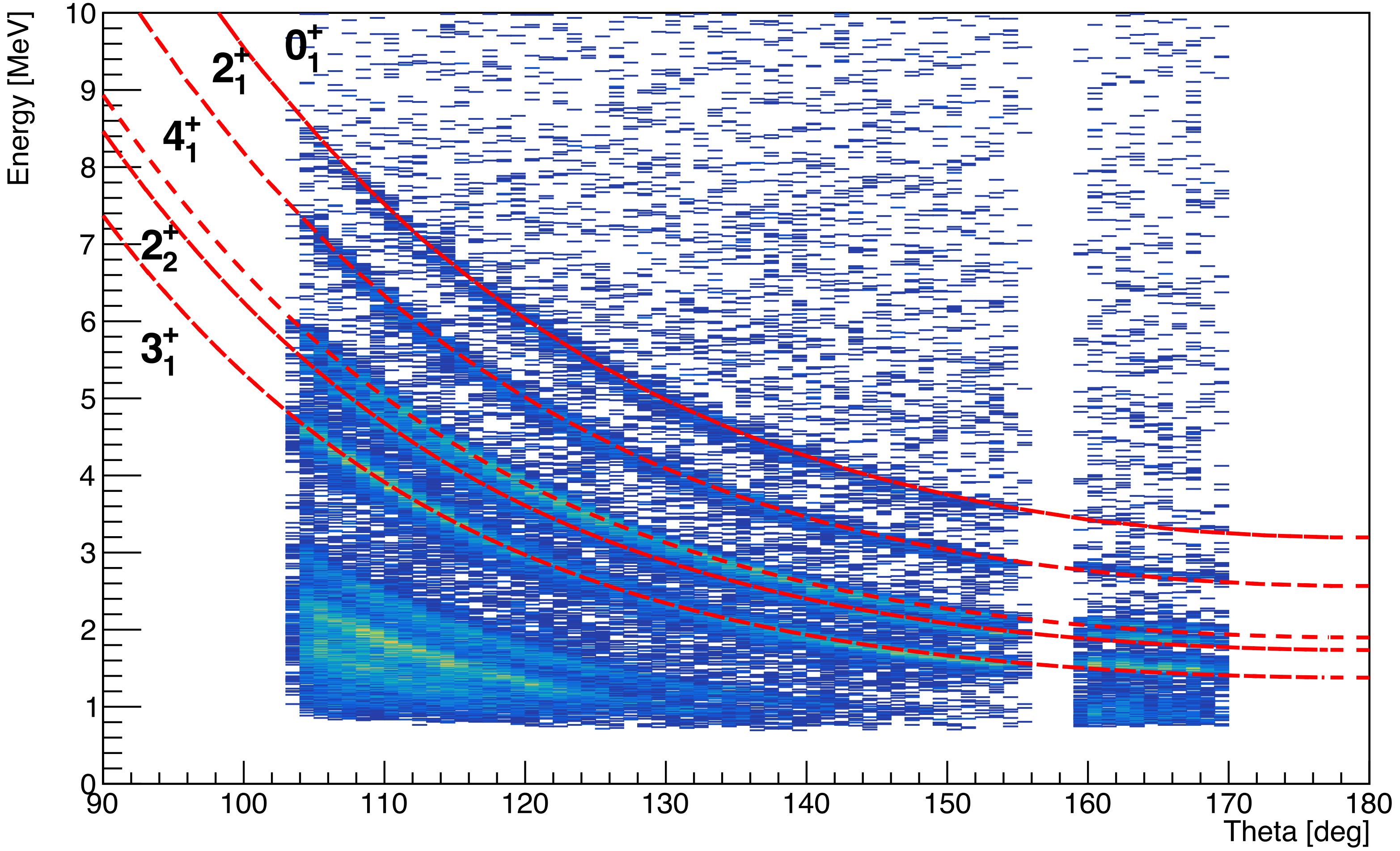
Range of femtoseconds

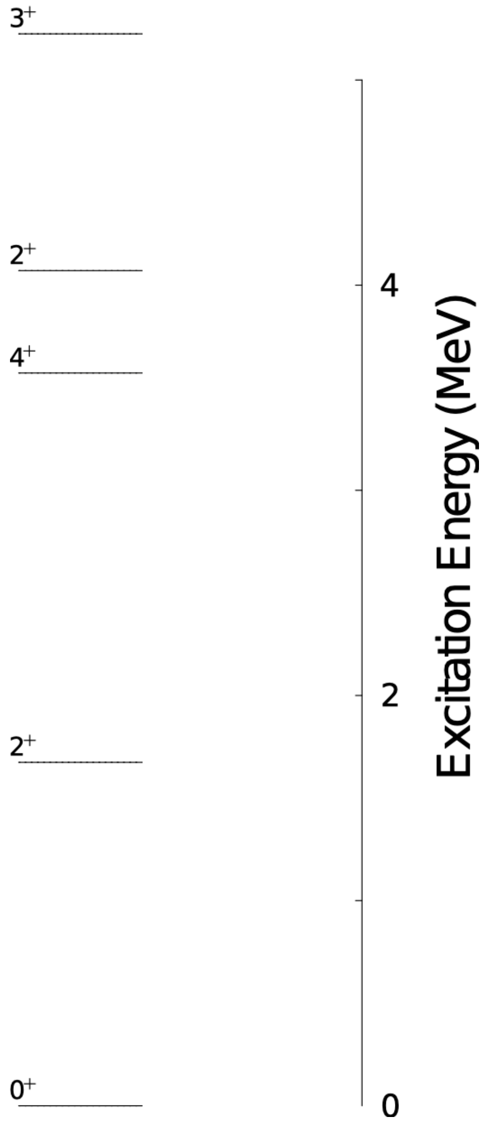
Part III:
γ-particle spectroscopy

Kinematic lines

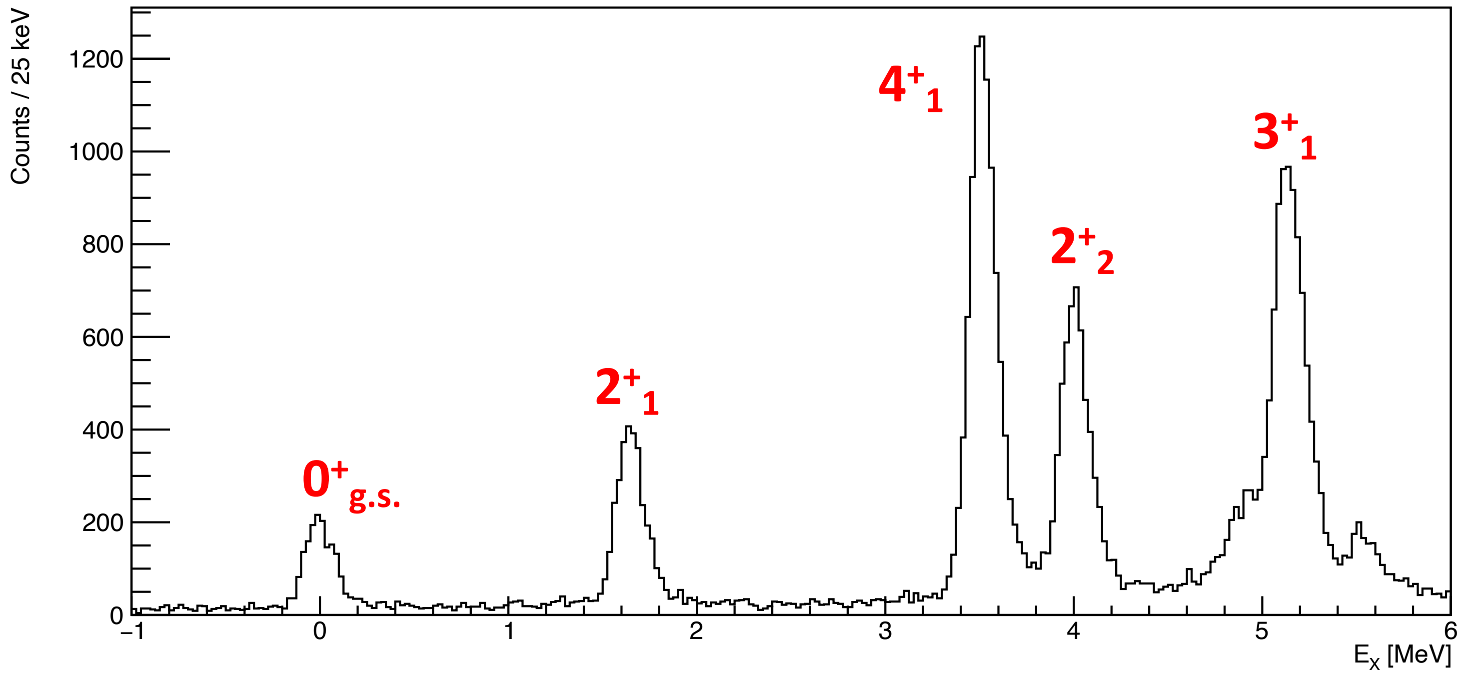


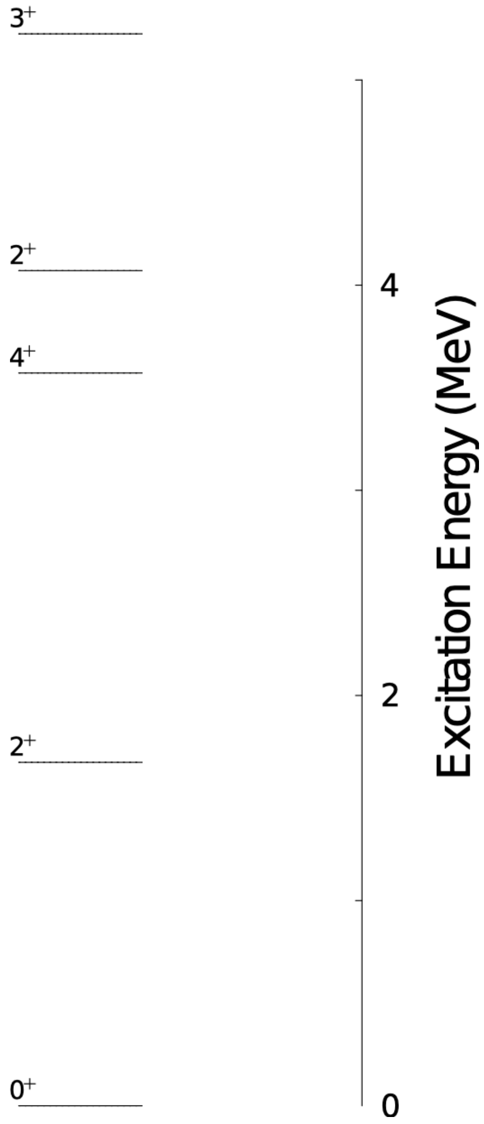
Kinematic lines



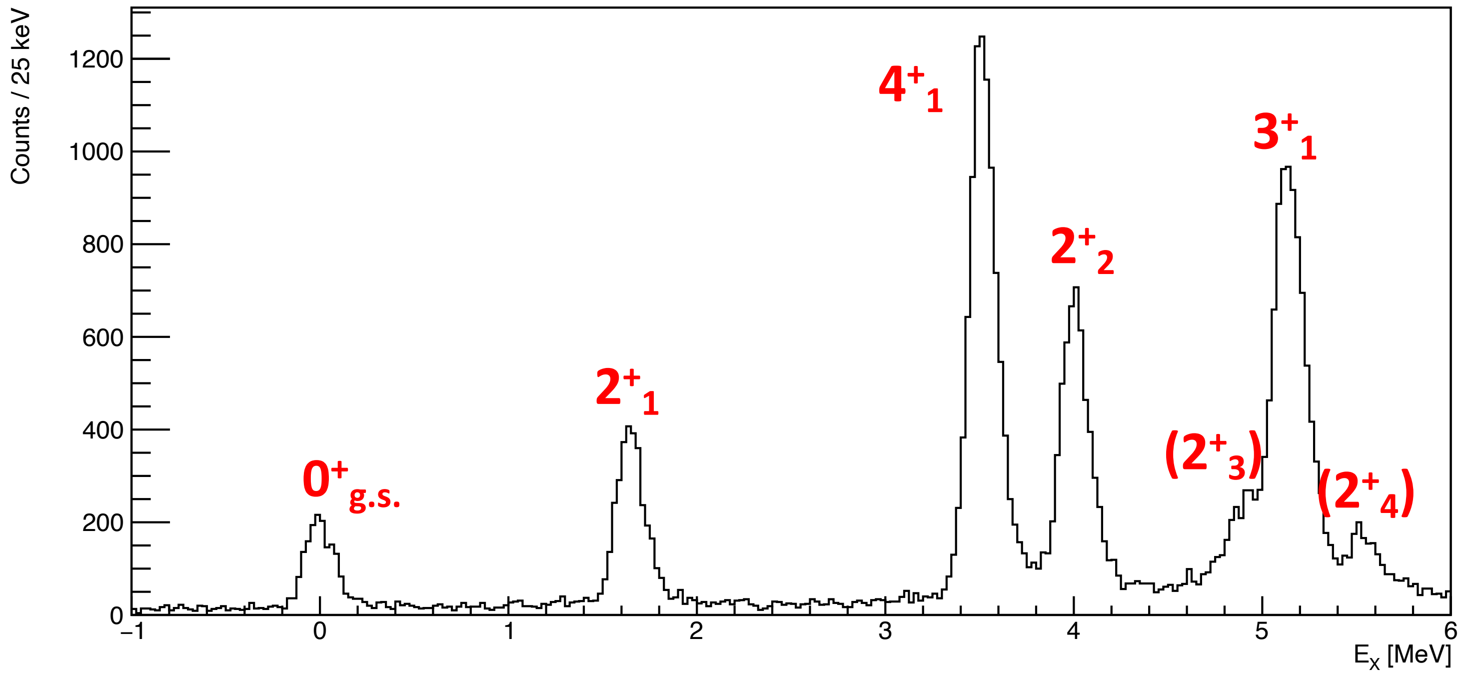


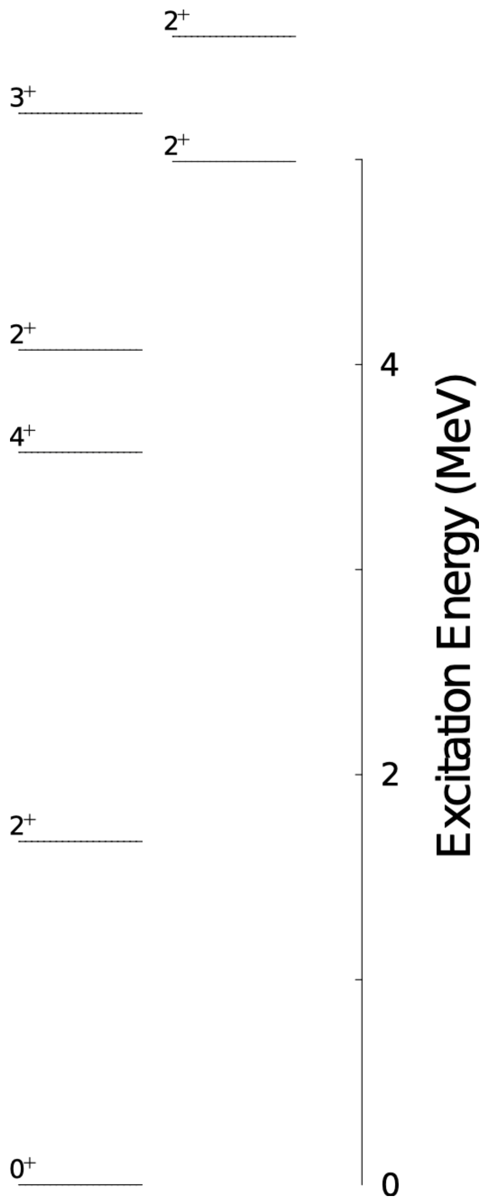
Excited states of ^{20}O



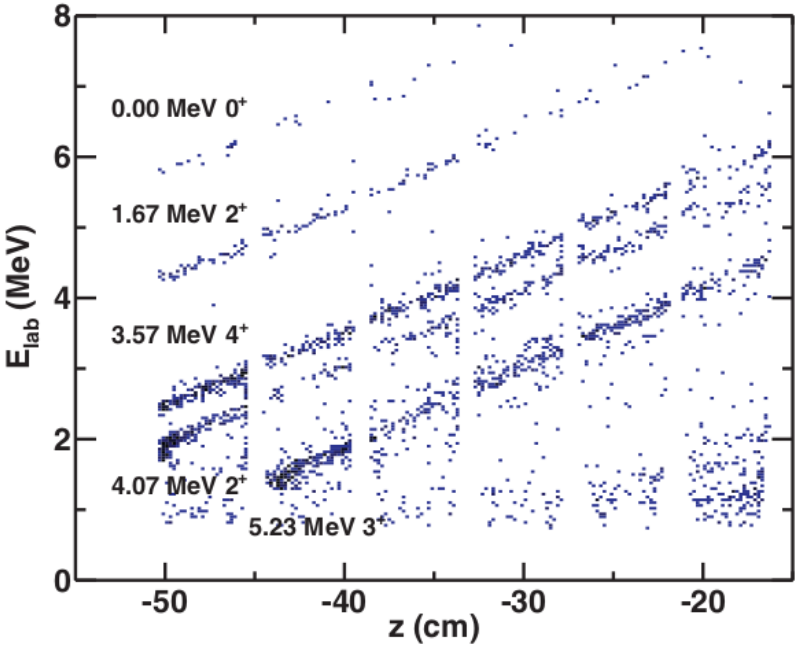


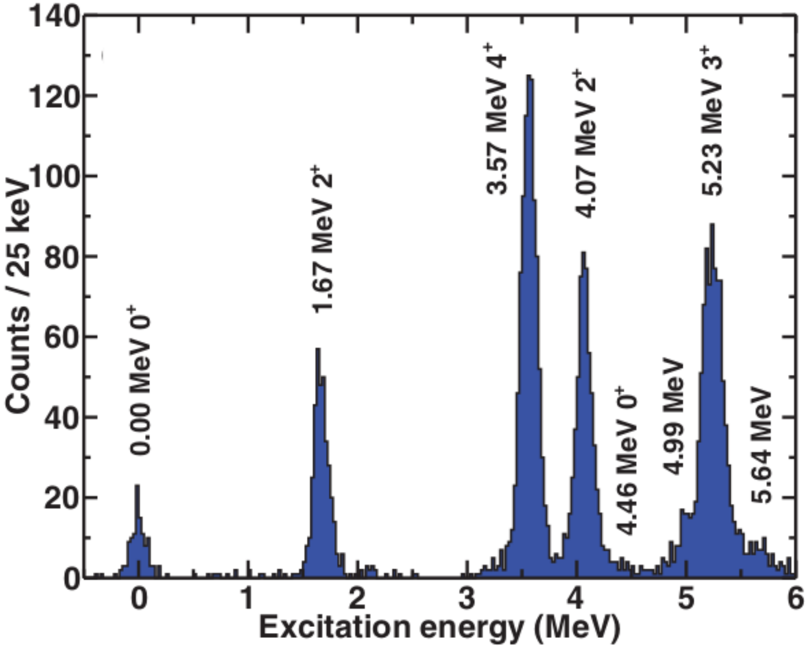
Excited states of ^{20}O



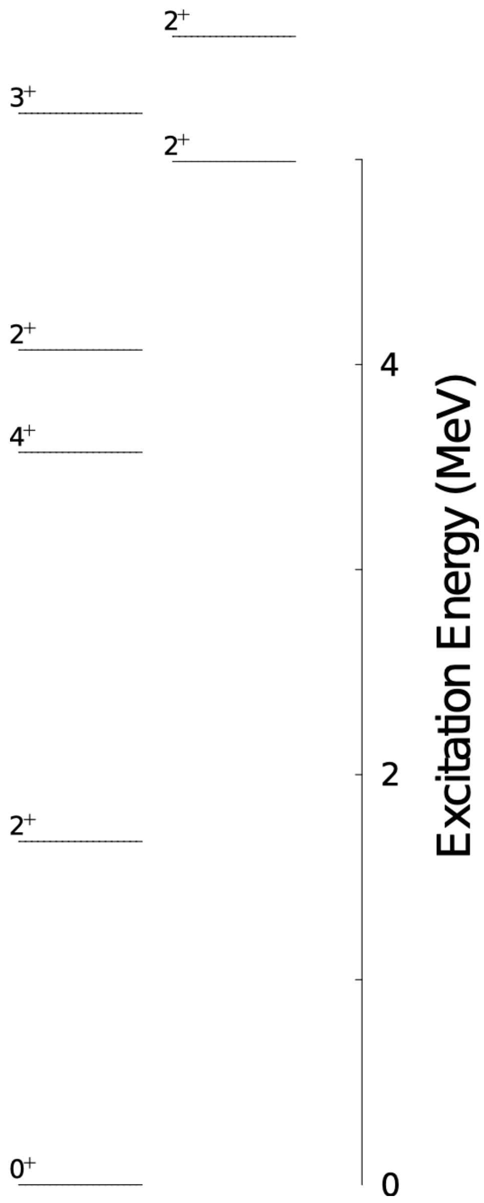


Excited states of ^{20}O

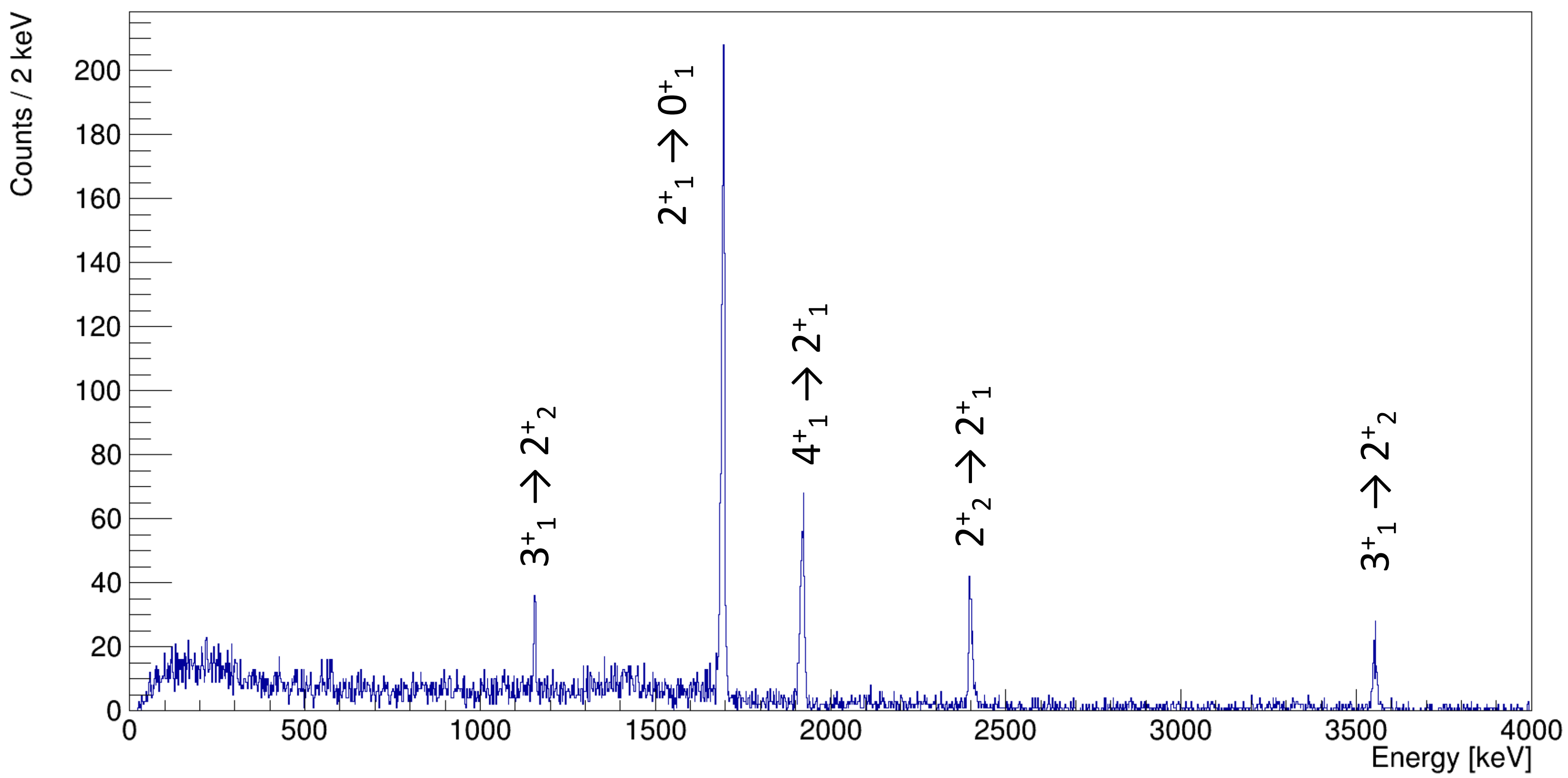


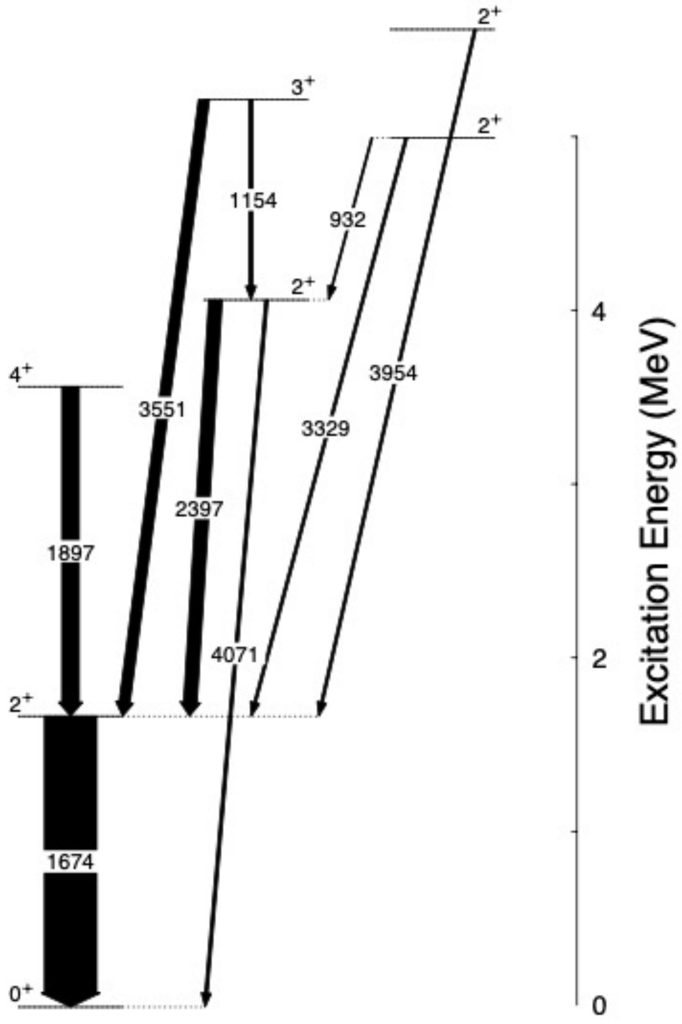


C. Hoffman et al., PRC **85**, 054318 (2012)

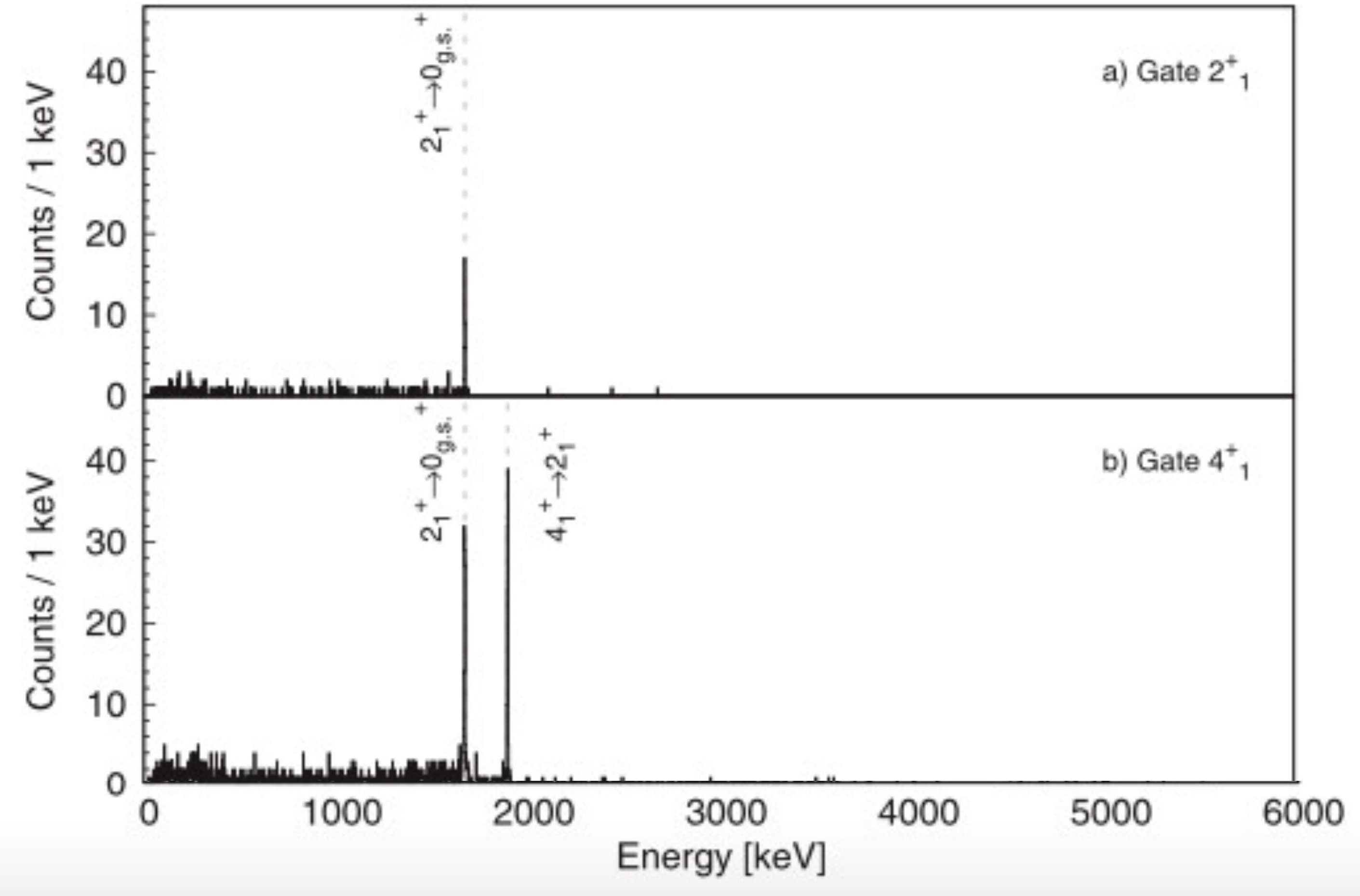


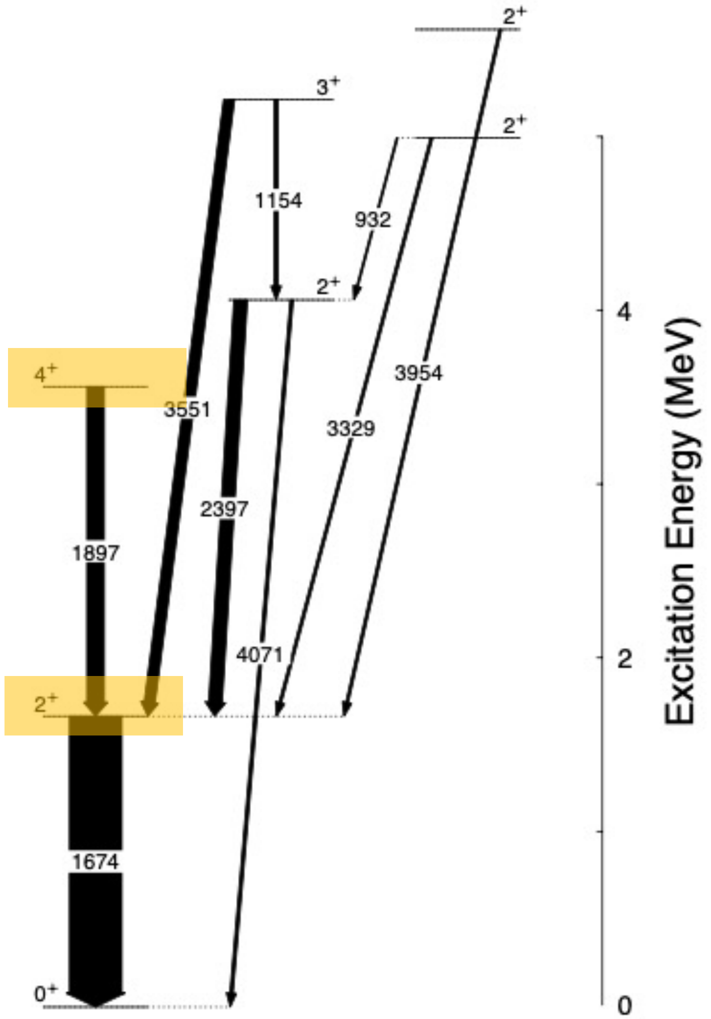
γ spectroscopy of ^{20}O



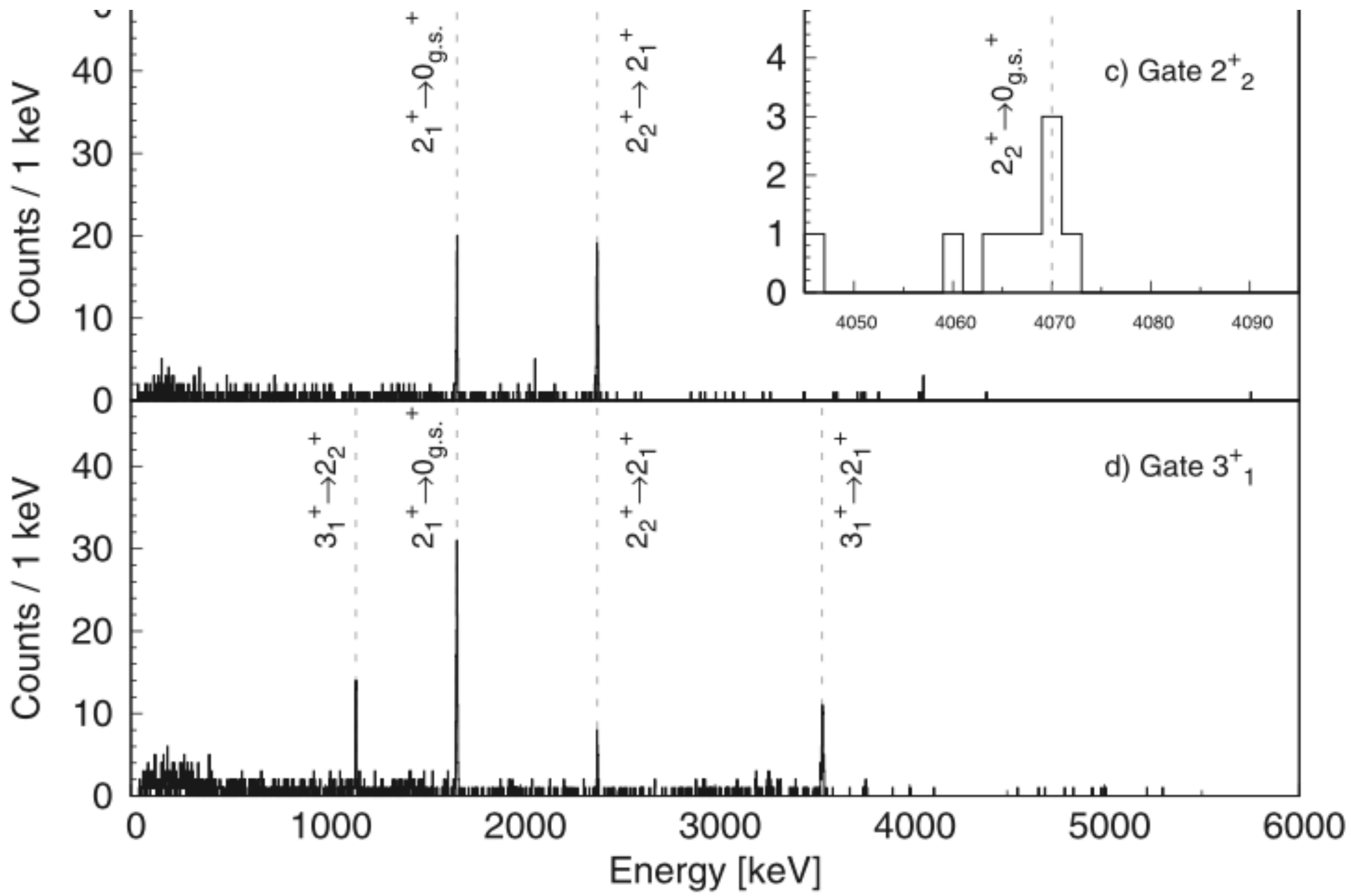


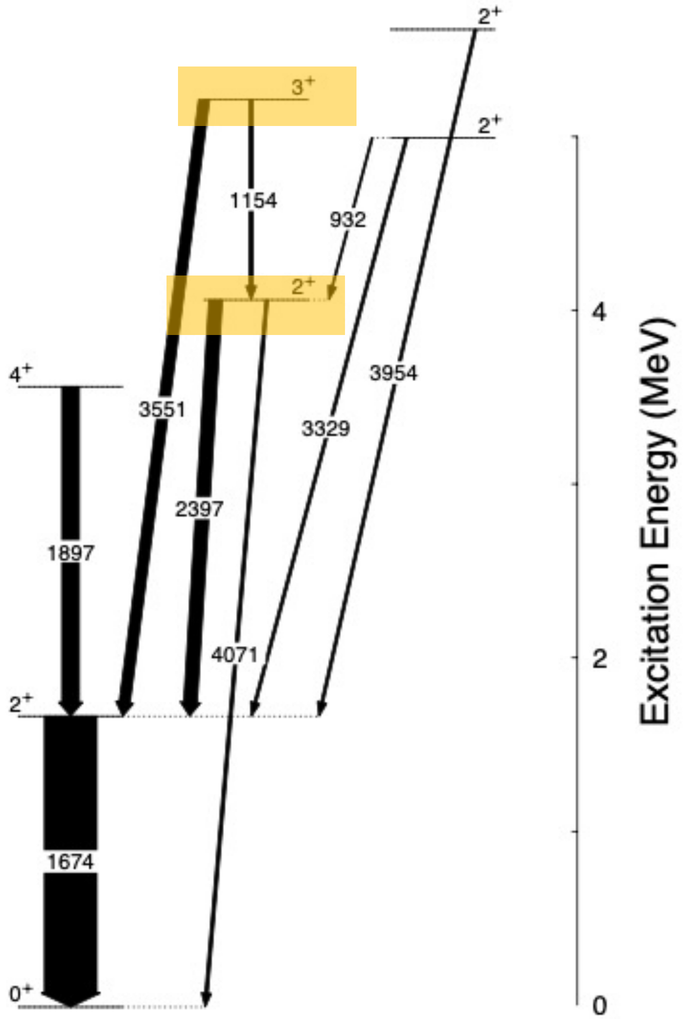
γ spectroscopy of ^{20}O





γ spectroscopy of ^{20}O

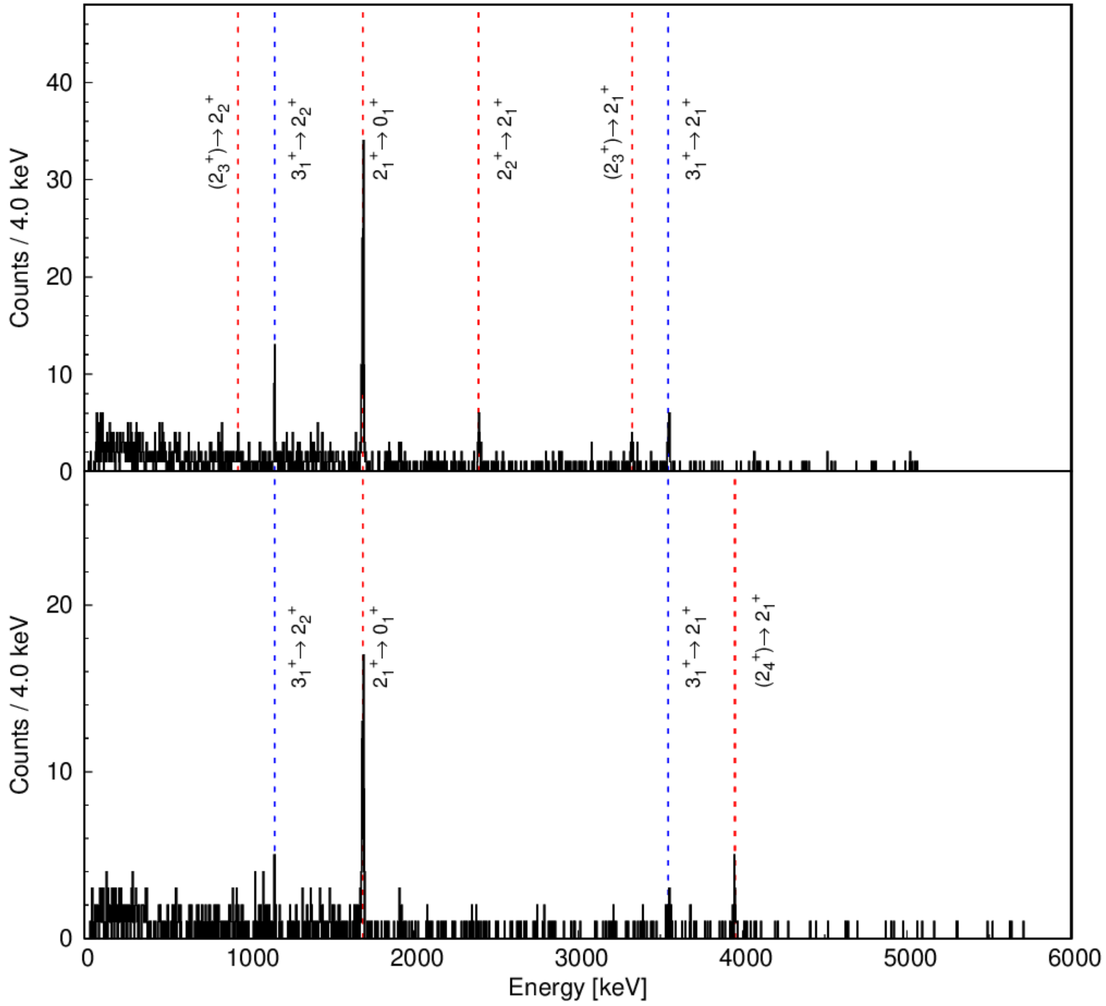


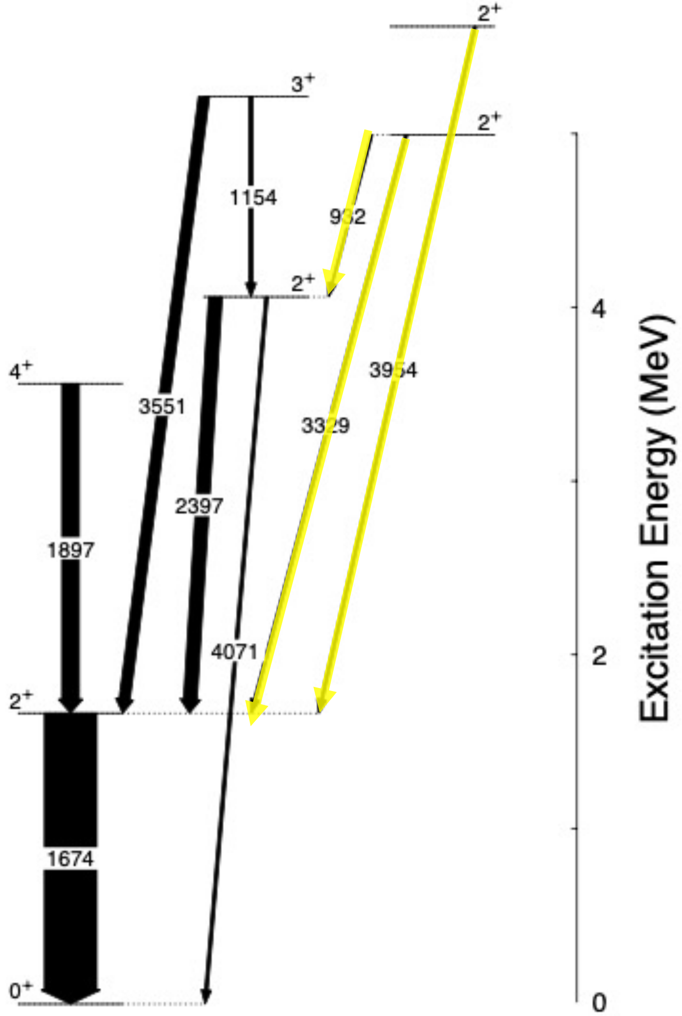


γ spectroscopy of ^{20}O

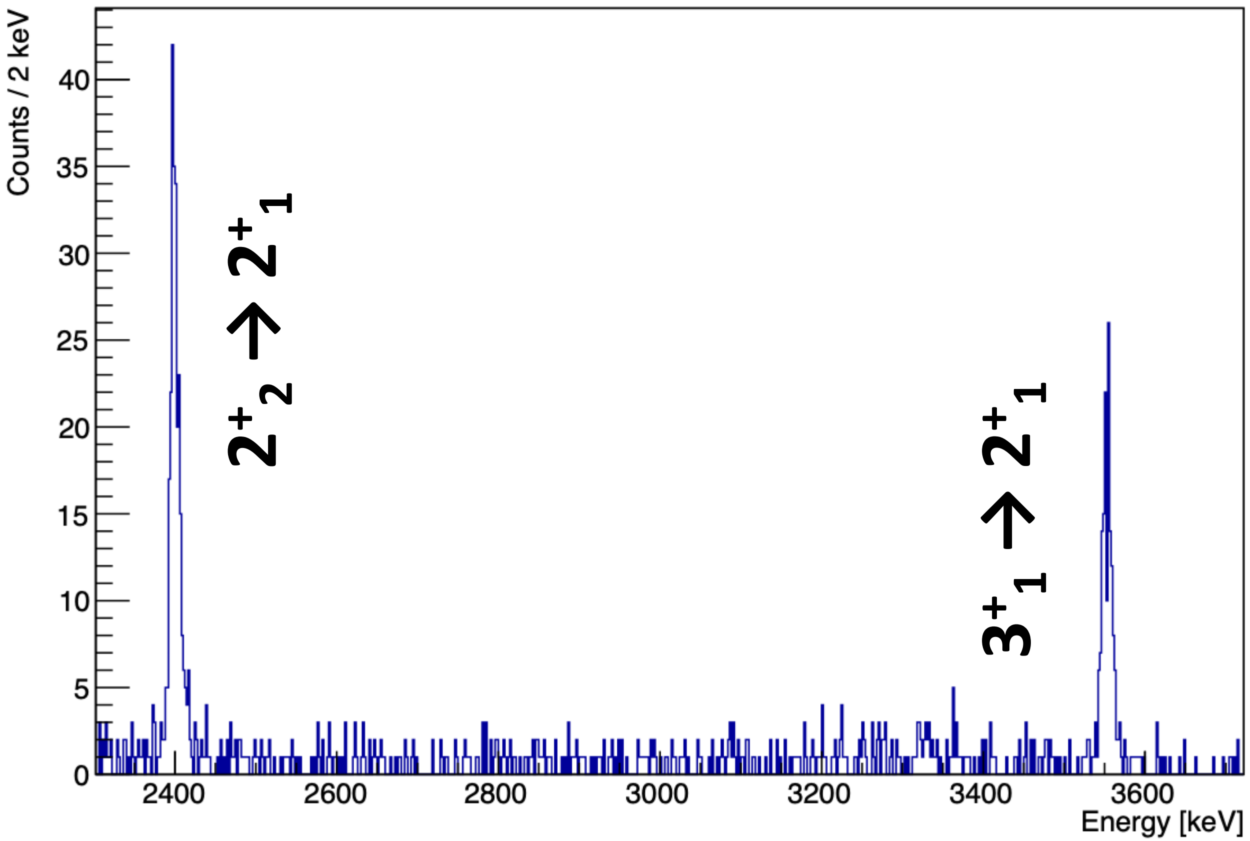
Gate 4.9 MeV

Gate 5.6 MeV



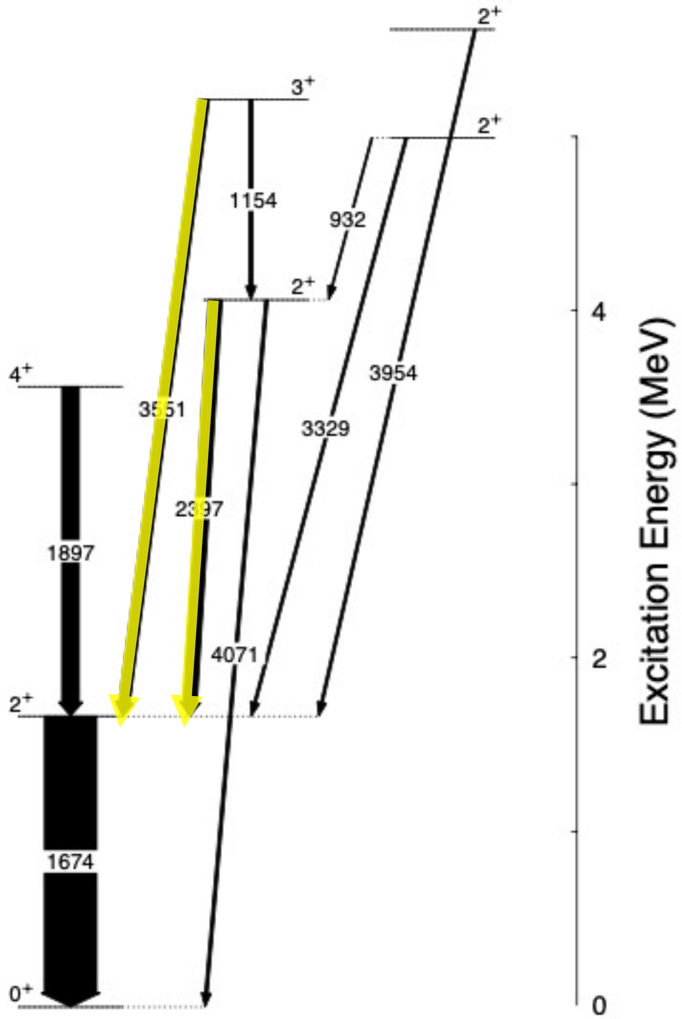


γ spectroscopy of ^{20}O

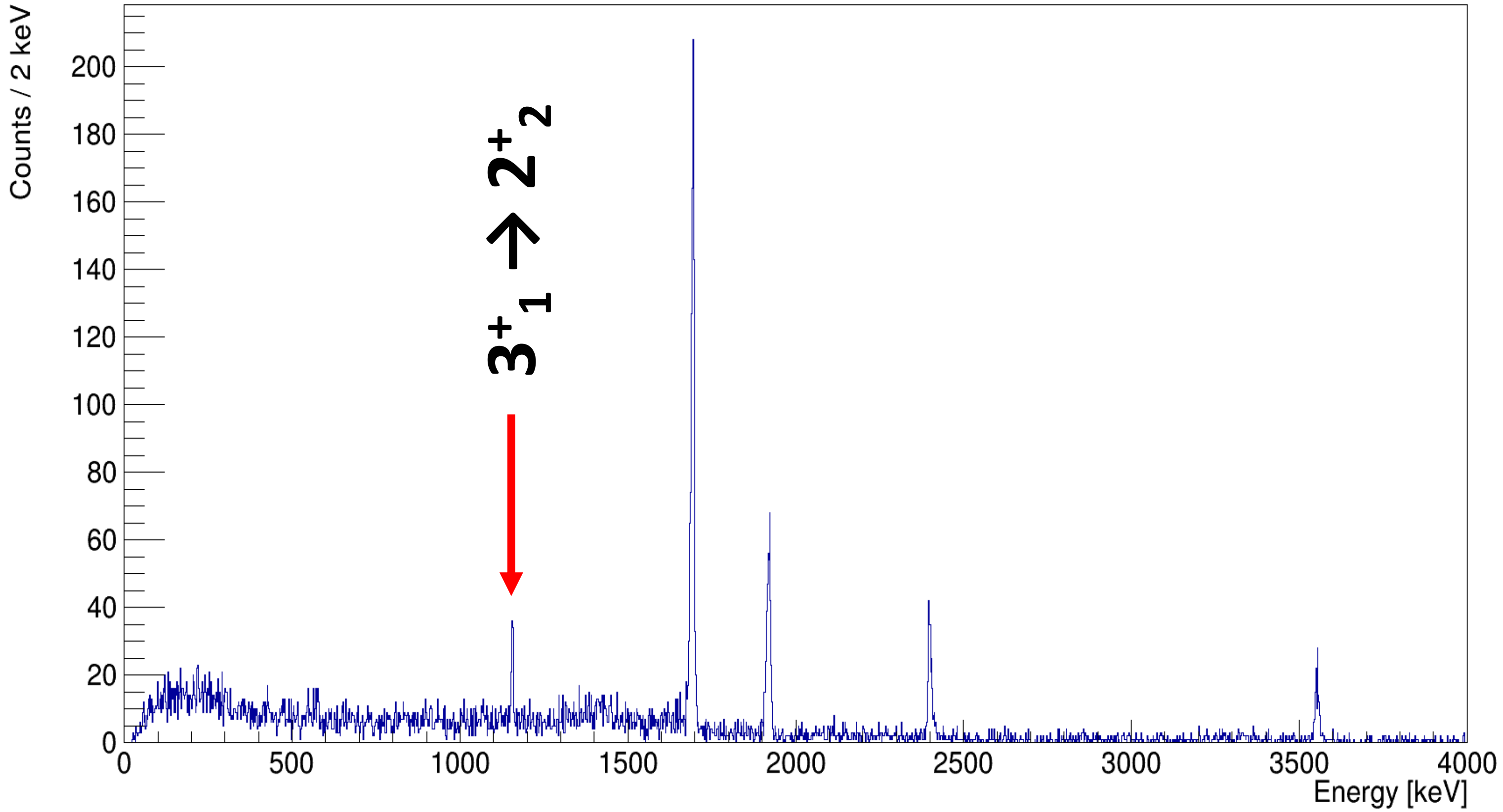


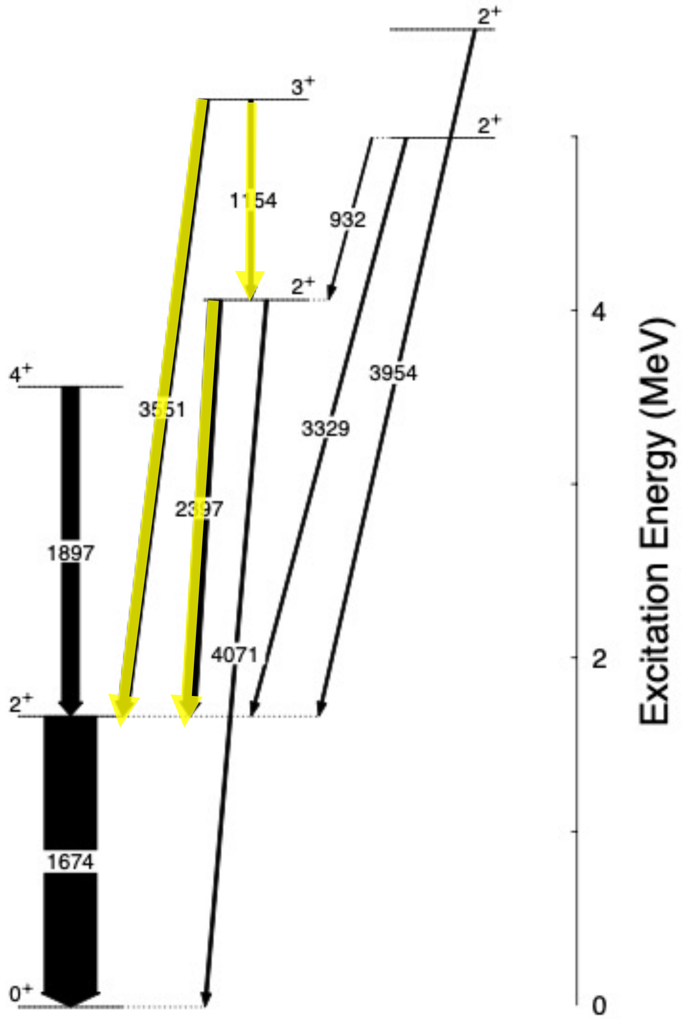
$2^+_2 \rightarrow 2^+_1$

$3^+_1 \rightarrow 2^+_1$

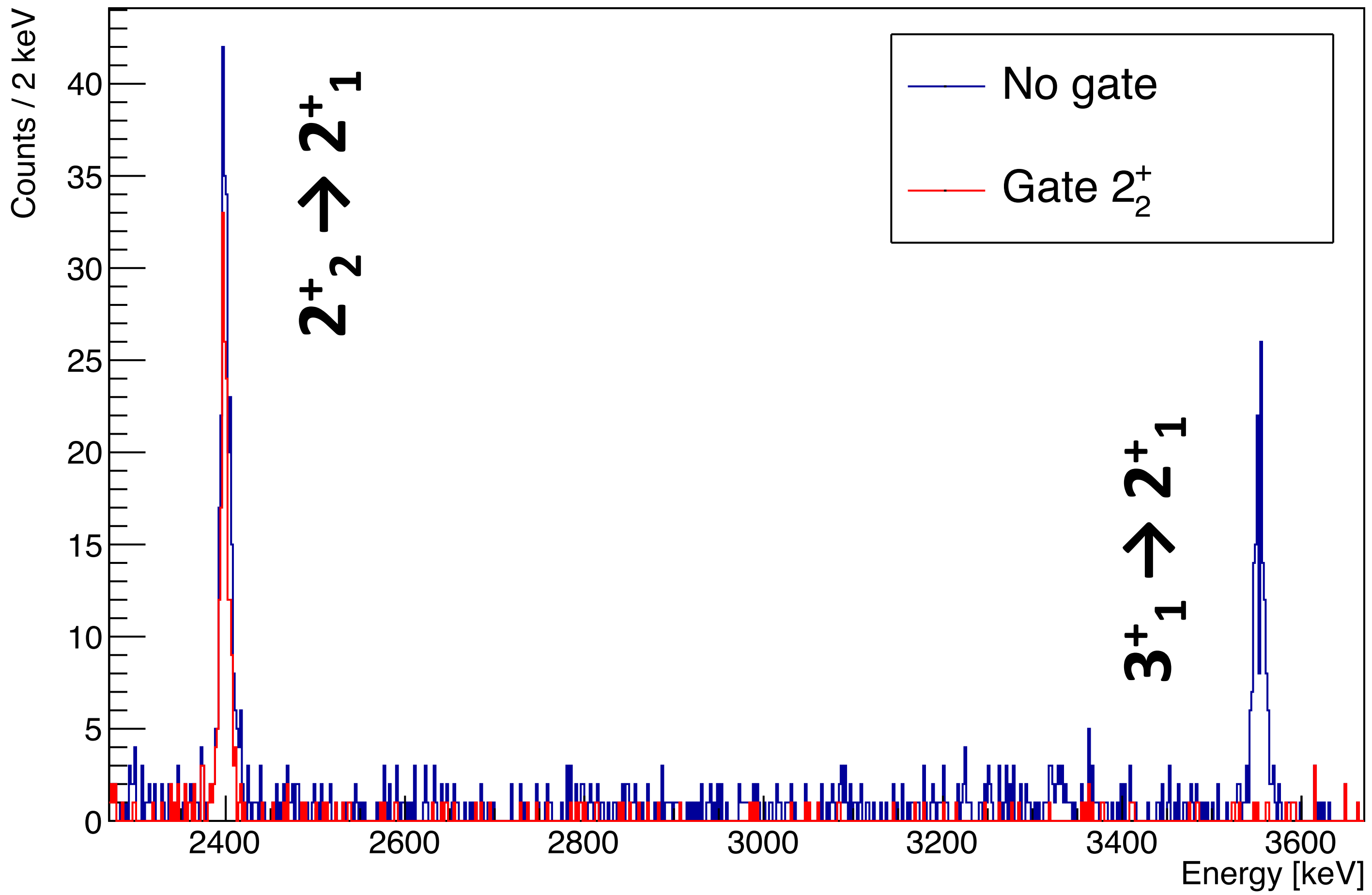


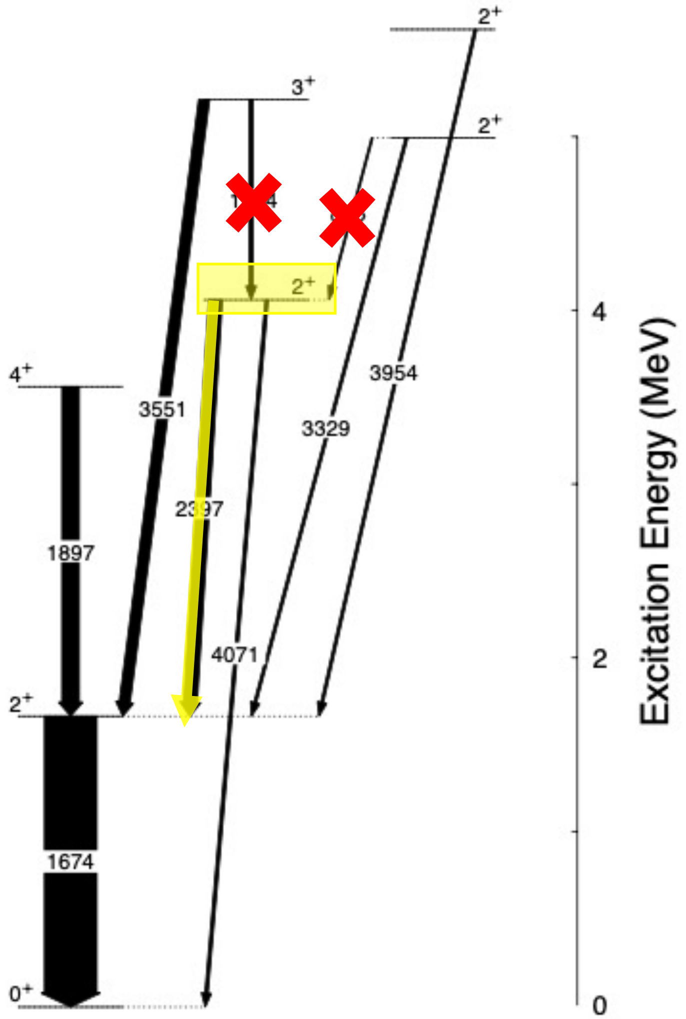
γ spectroscopy of ^{20}O



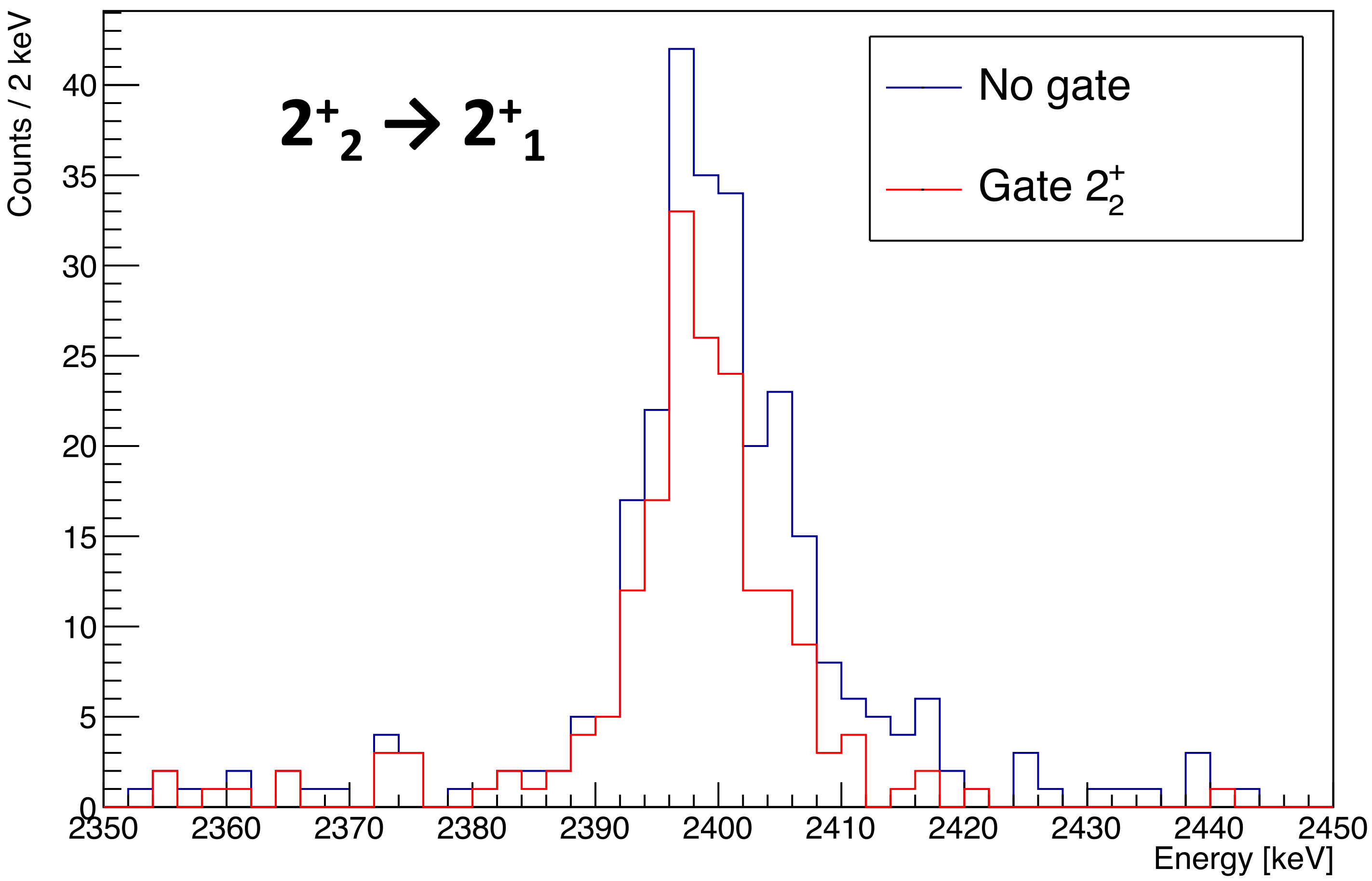


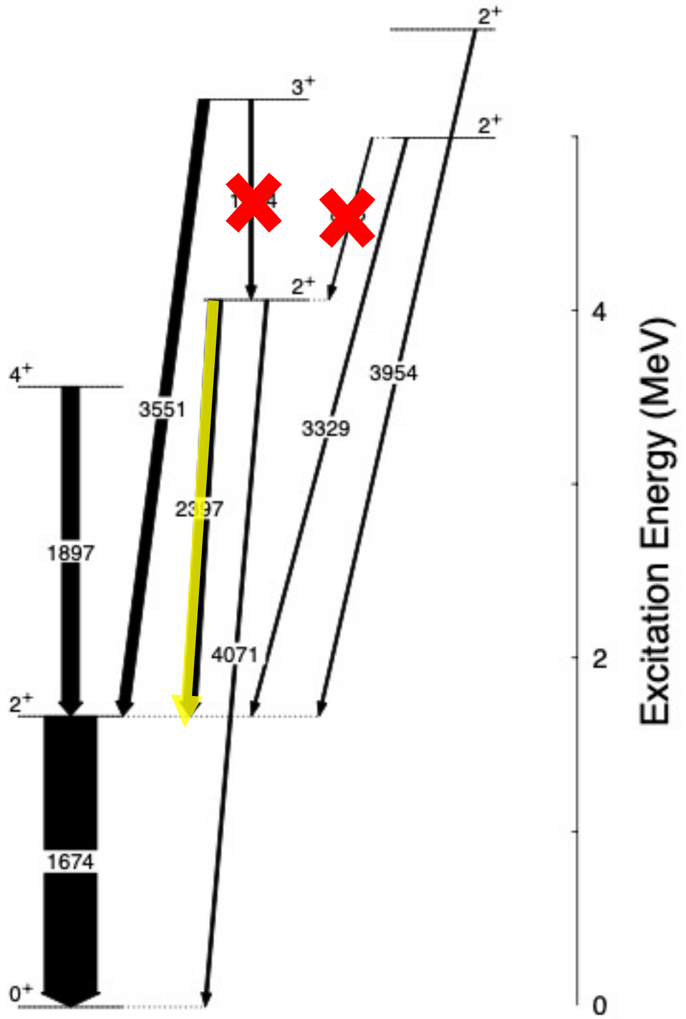
γ spectroscopy of ^{20}O





γ spectroscopy of ^{20}O





Part IV:
Optimization of the simulation

Monte Carlo simulation

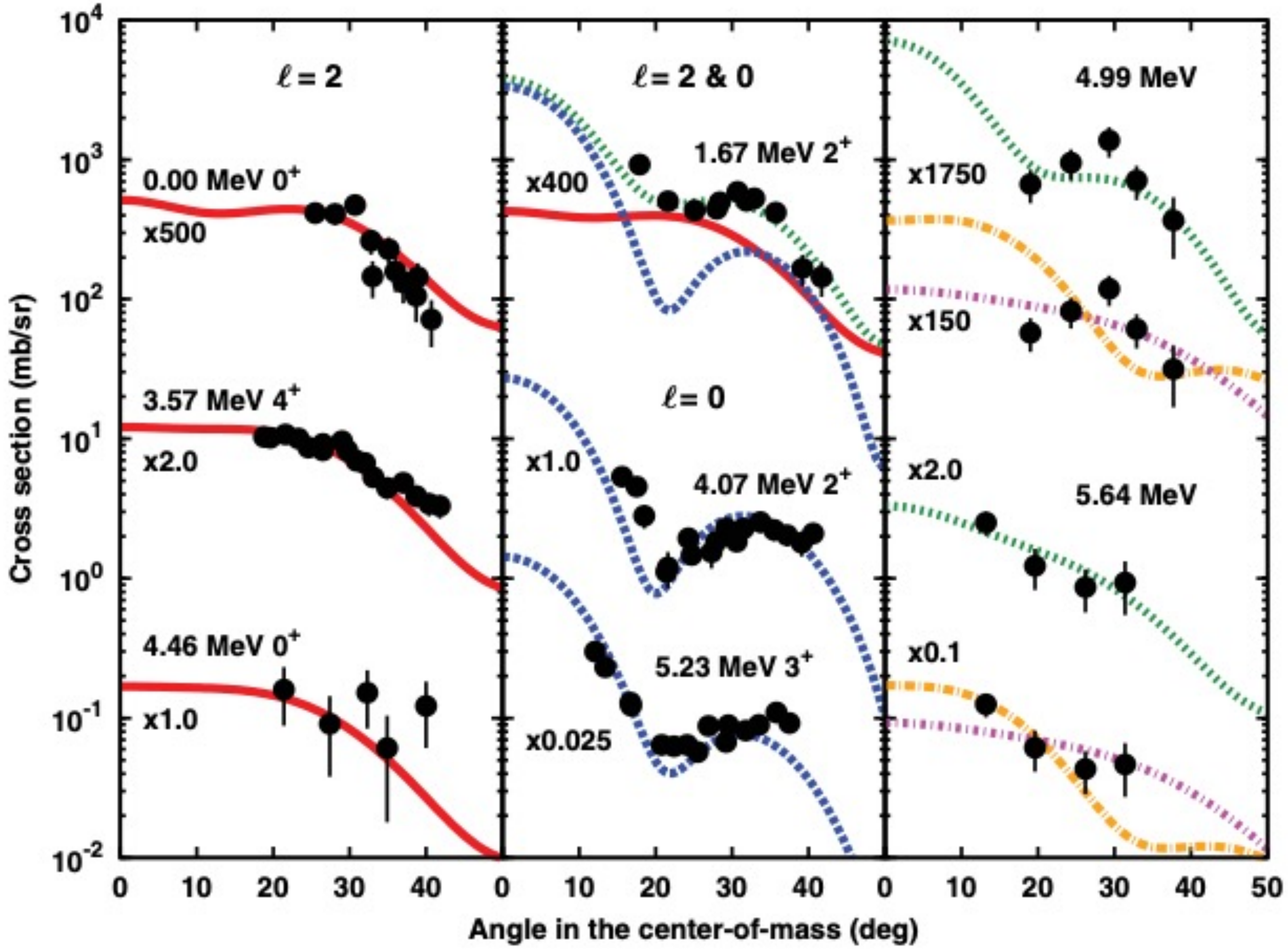
Complete geometry and performance of the setup reproduced in the AGATA Geant4 code.

Realistic parameters included:

- Measured energy and position resolution of the detectors;
- Disabilitation of missing strips of MUGAST;
- Particle angular distribution;
- Energy Loss;
- Energy tuning…

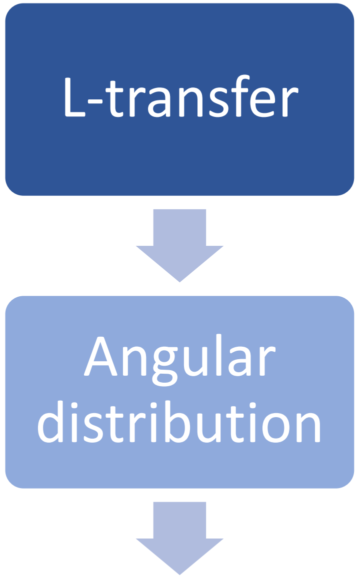
Angular distribution

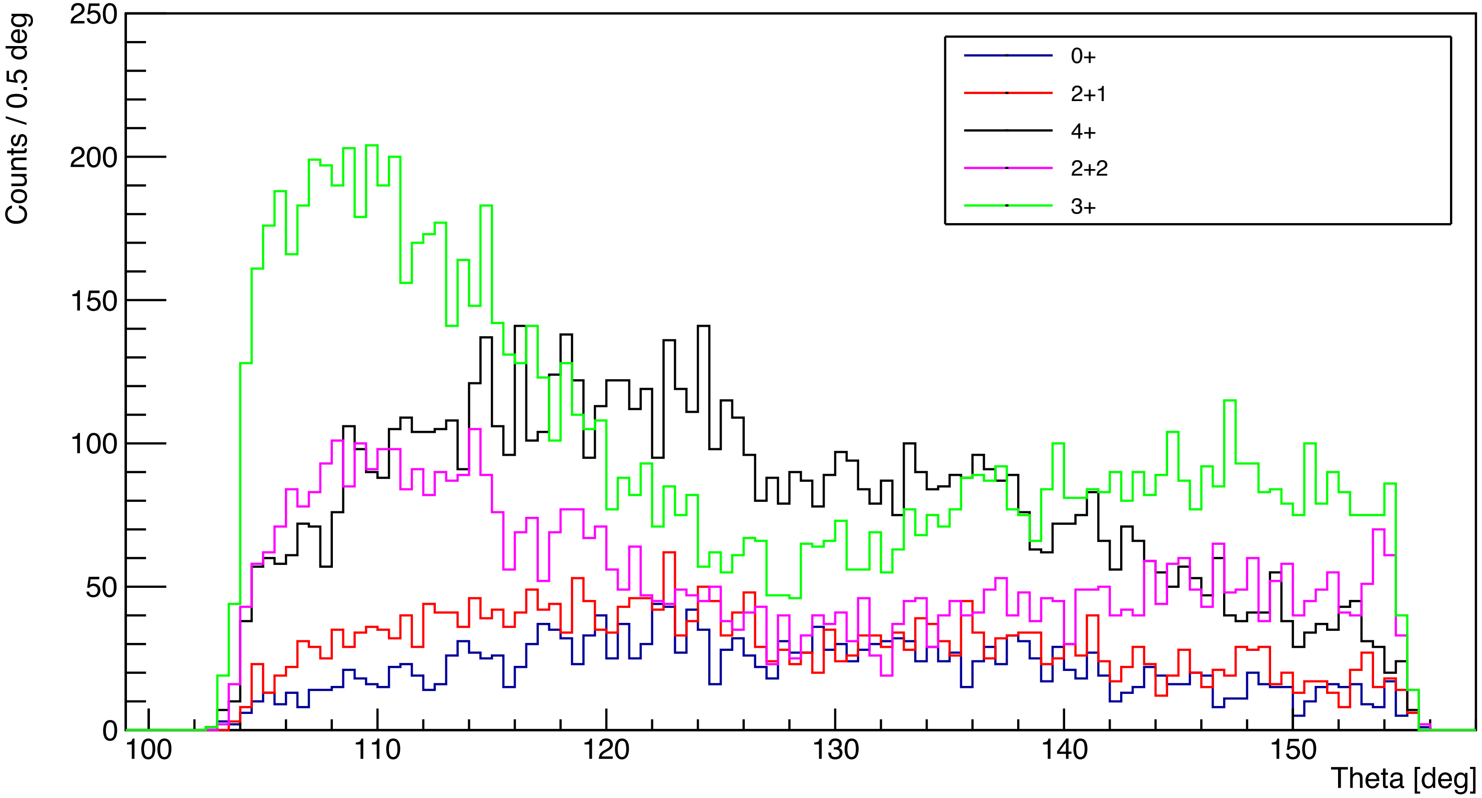
L-transfer



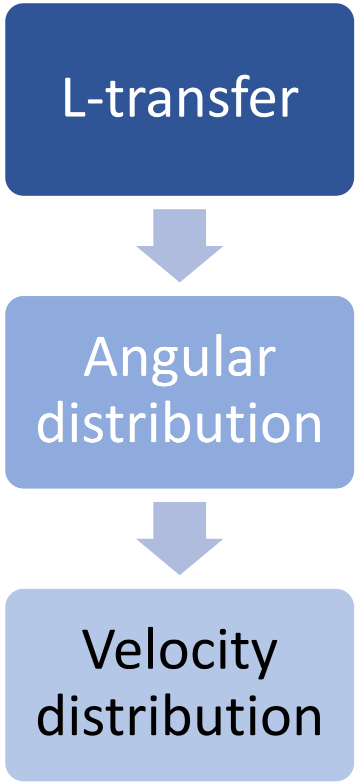
C. Hoffman et al., PRC **85**, 054318 (2012)

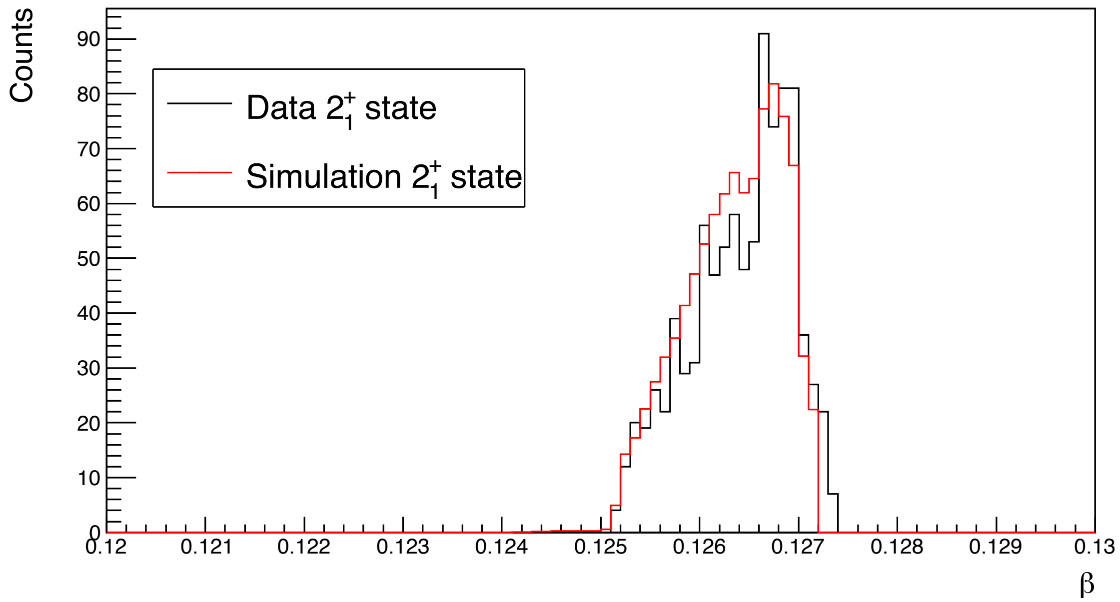
Angular distribution

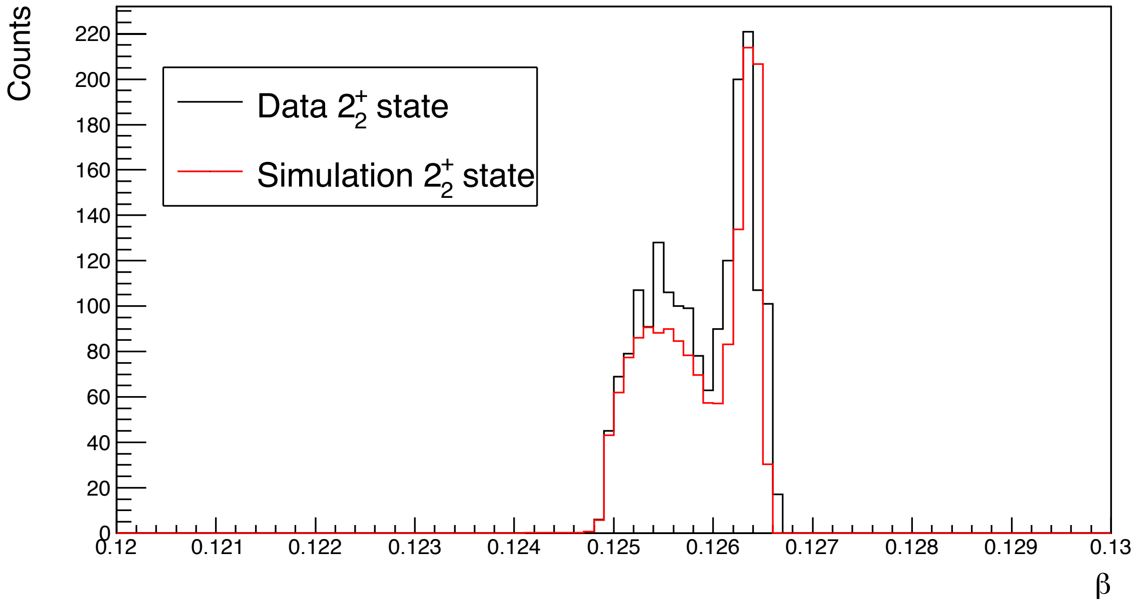




Angular distribution



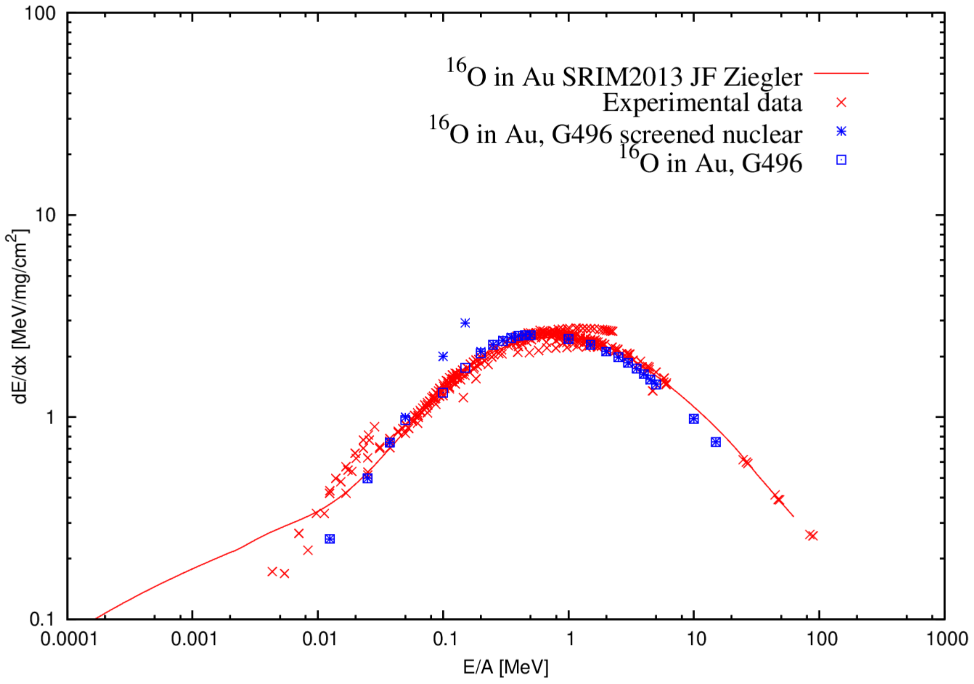


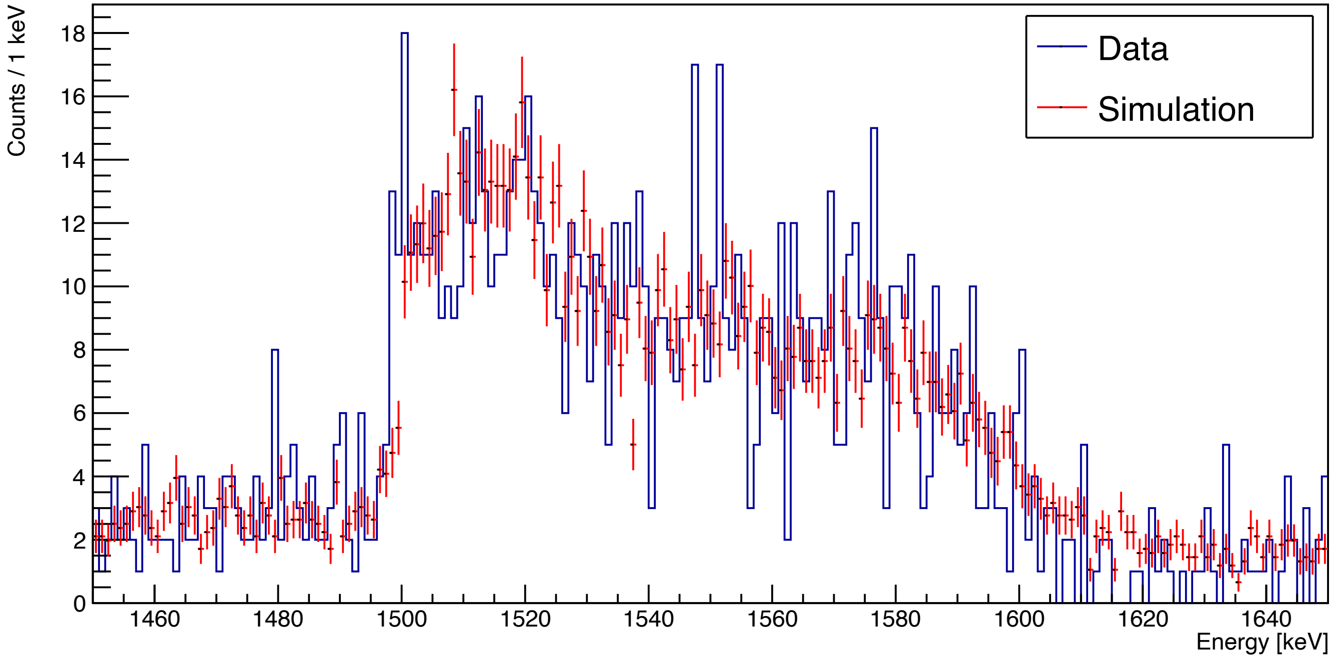


I. Zanon, Il Nuovo Cimento **44 C**, 83 (2021)

Energy Loss

Experimental data agree with simulations.

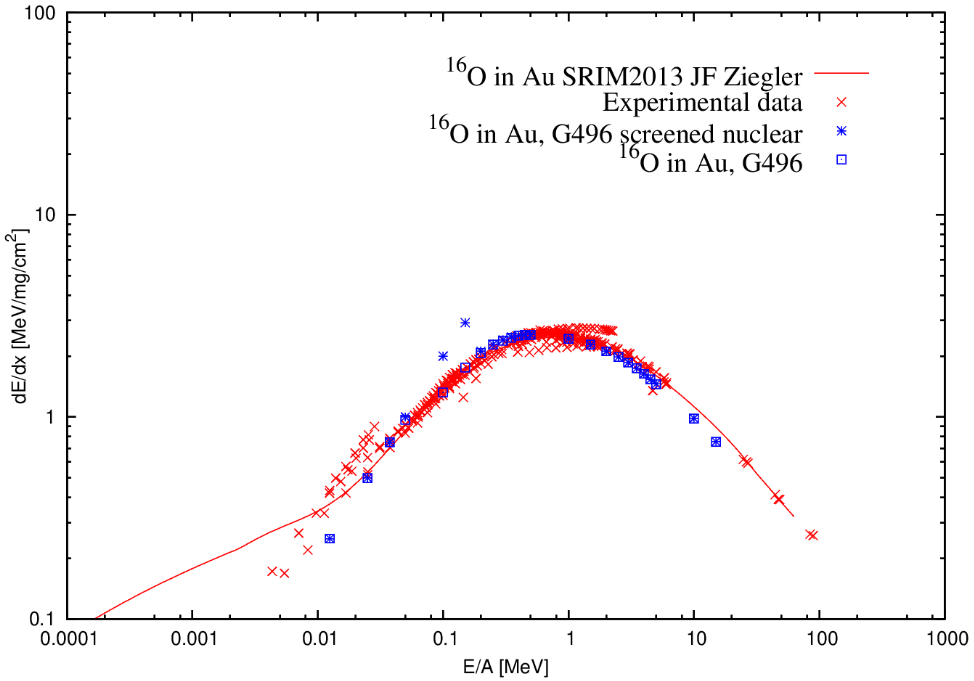


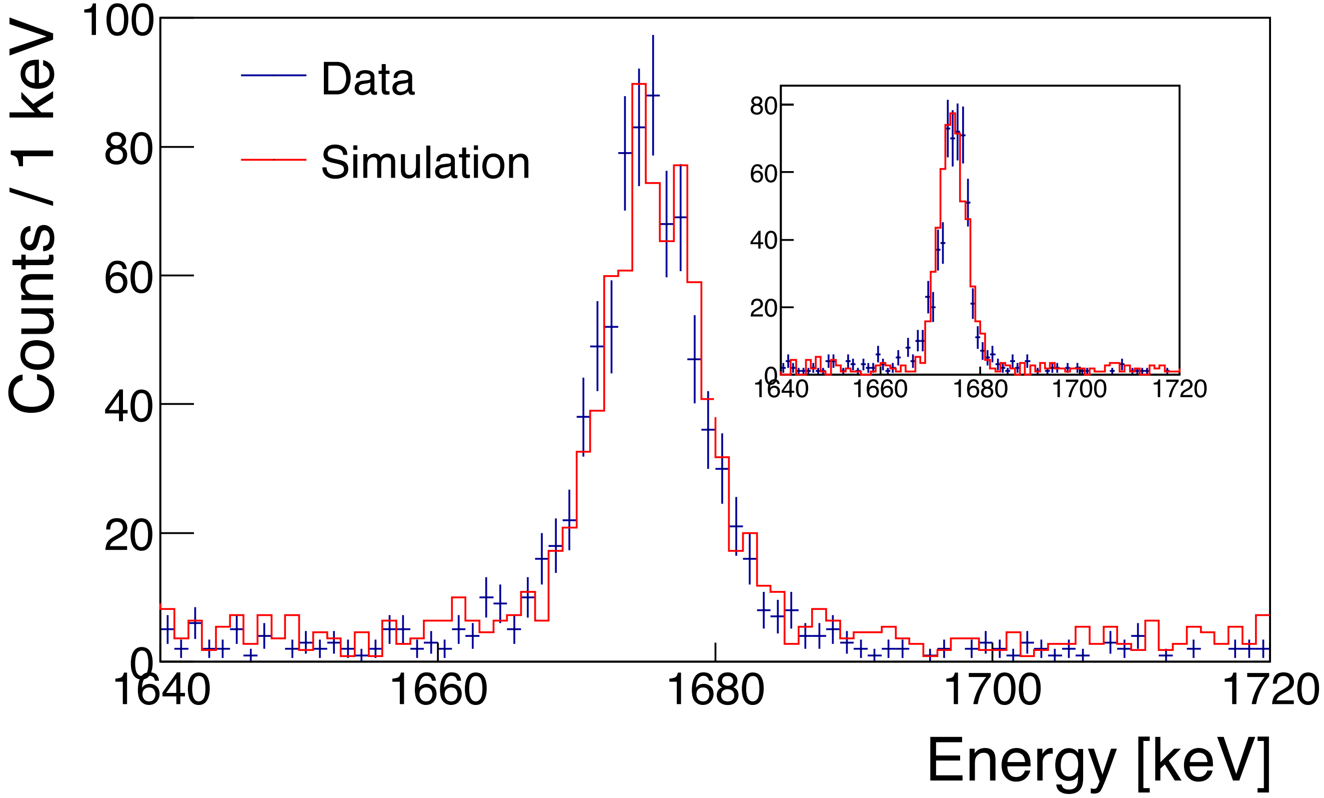


$2^+_1 \rightarrow 0^+_1$ chosen because of its long τ.
The energy loss in the degrader is reproduced.

Energy Loss

Experimental data agree with simulations.

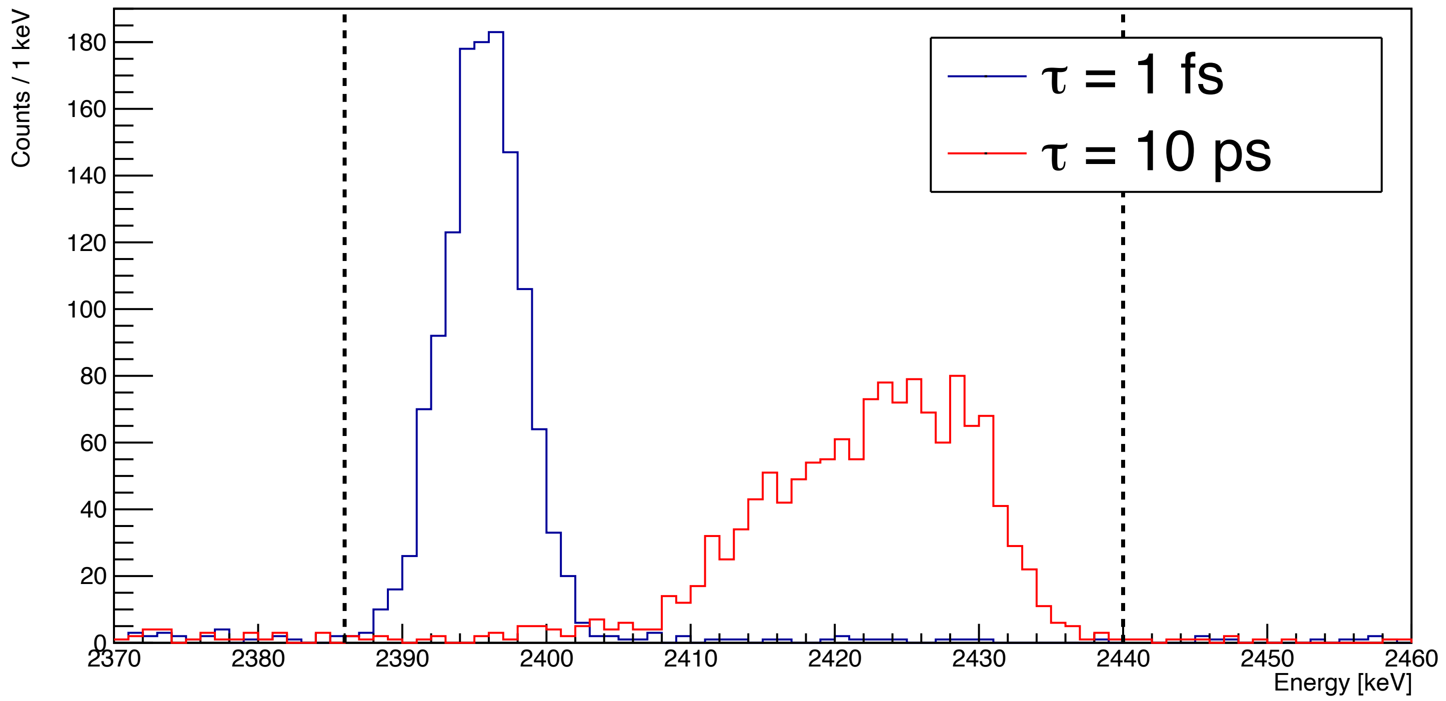




$2^+_1 \rightarrow 0^+_1$ chosen because of its long τ.
The energy loss in the degrader is reproduced.

Part V:
Lifetime measurements

Lifetime measurements



Two degrees of freedom:

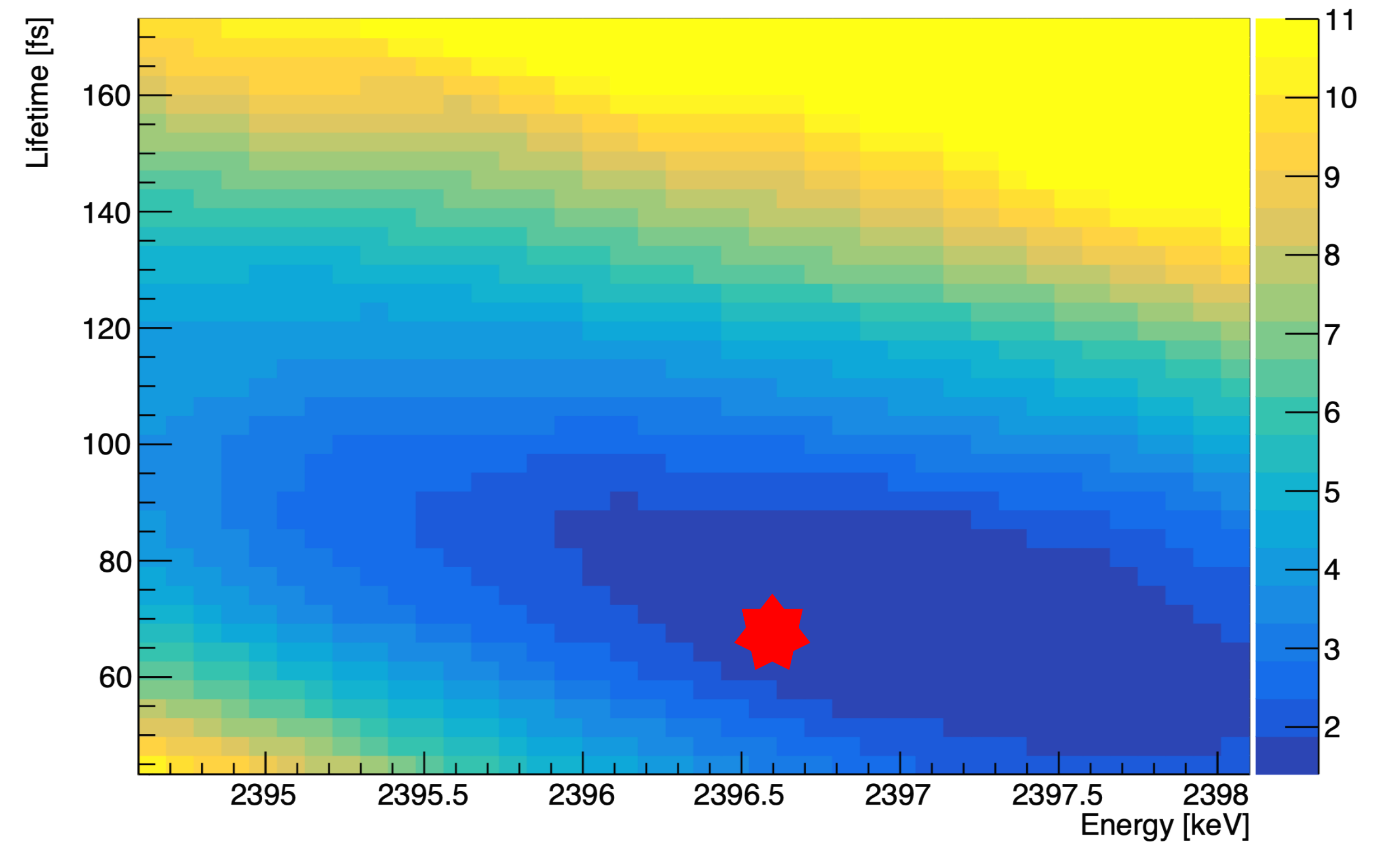
- The lifetime of the state;
- The energy of the transition.

Two series of simulations:

- Coarse scan;
- Fine scan.

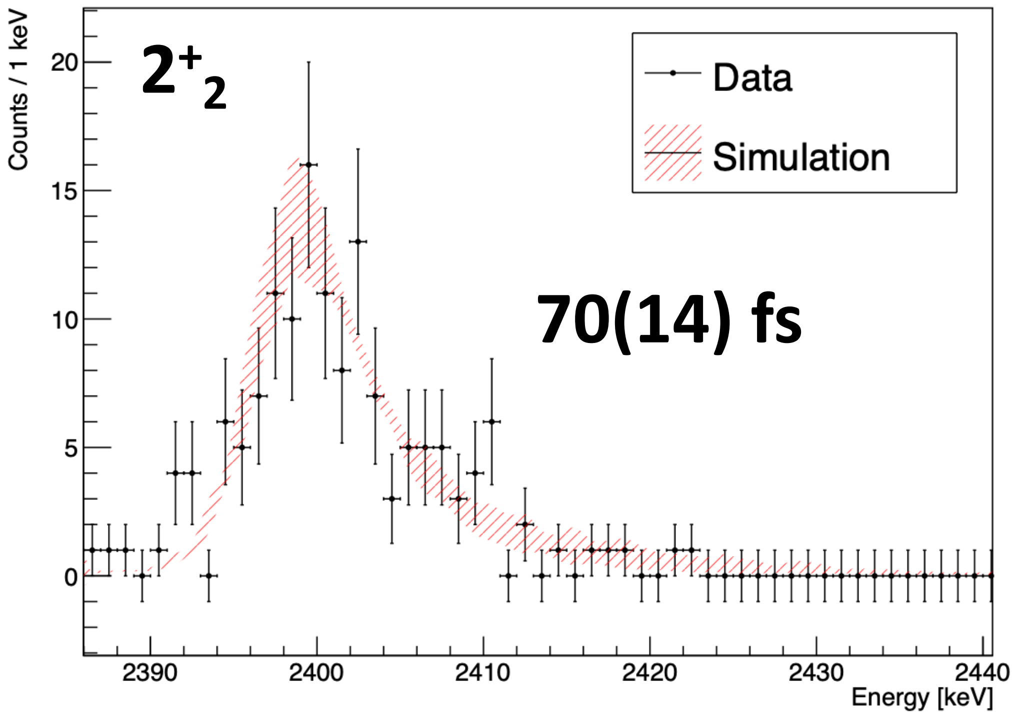
Range of energy for the comparison based on the Doppler shift.

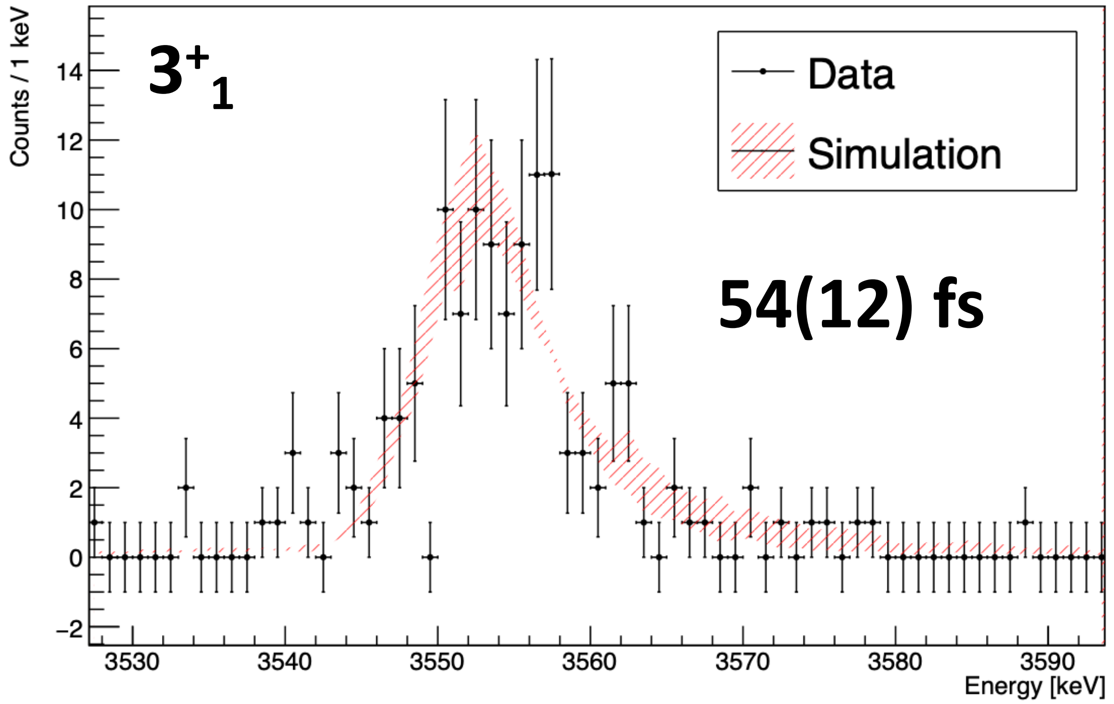
Lifetime measurements



- Gate on the E_X of 2^+_2
- Best energy for 2396.6 keV;
- Best lifetime value 70 fs;
- Least-χ^2 value below 2;
- Statistical errors evaluated using the $\Delta\chi^2$ method.

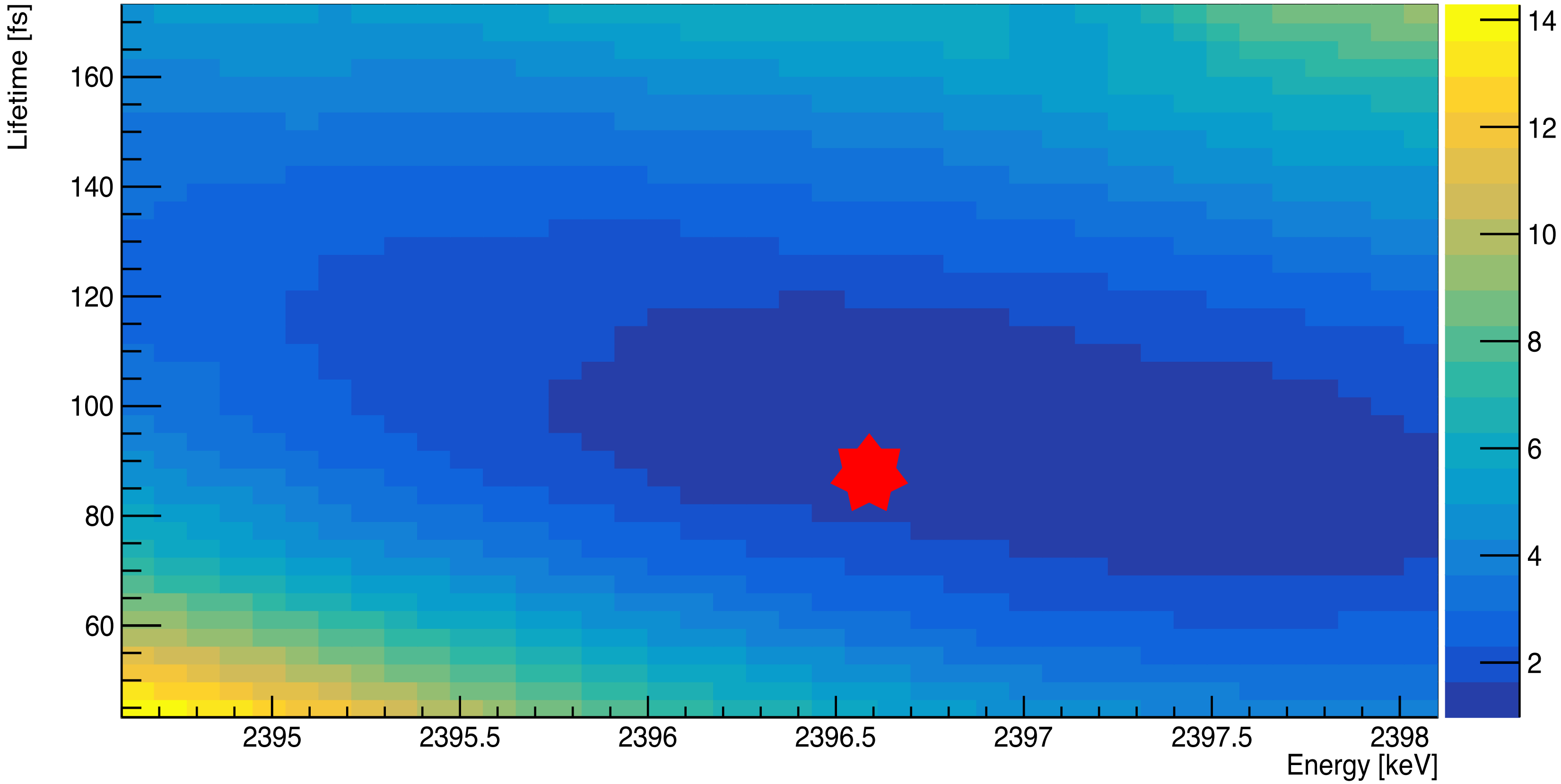
Lifetime measurements





Systematic errors around 5%

Lifetime measurements



No E_X gate 2^+_2

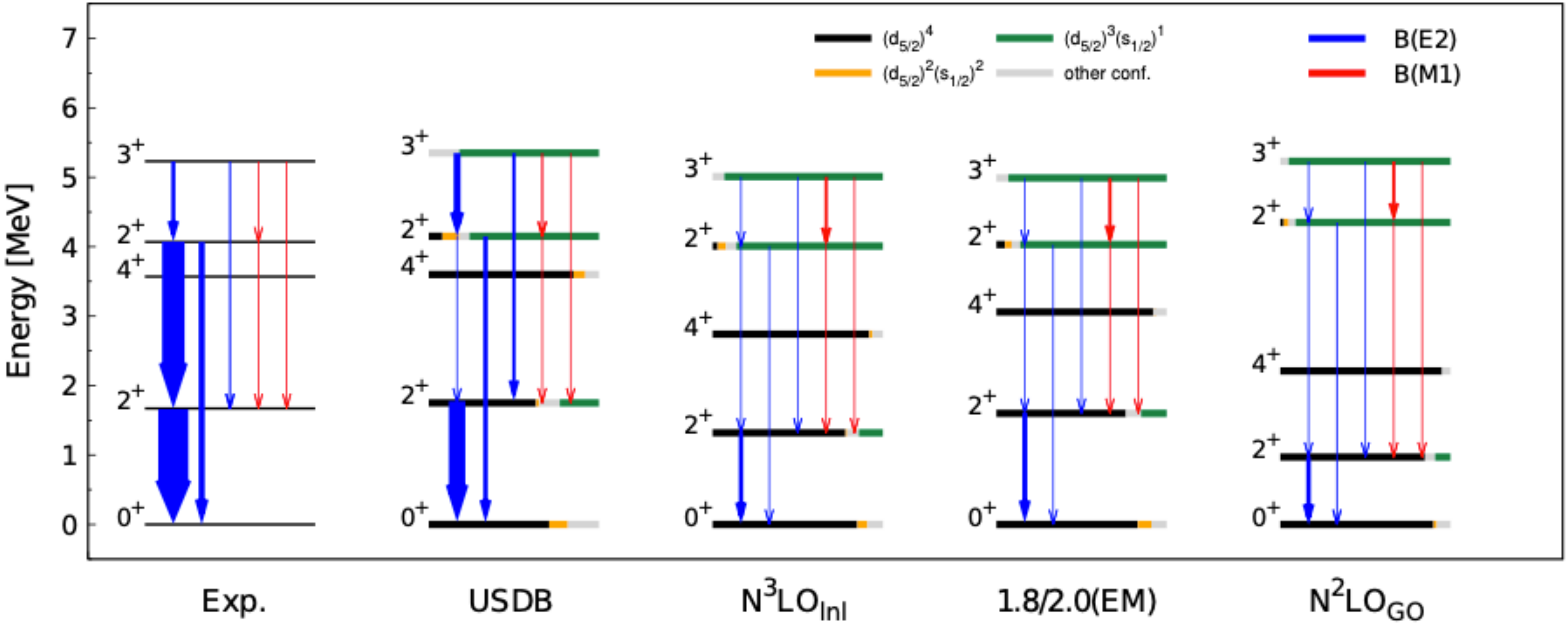
τ = 104(15) fs

49% longer

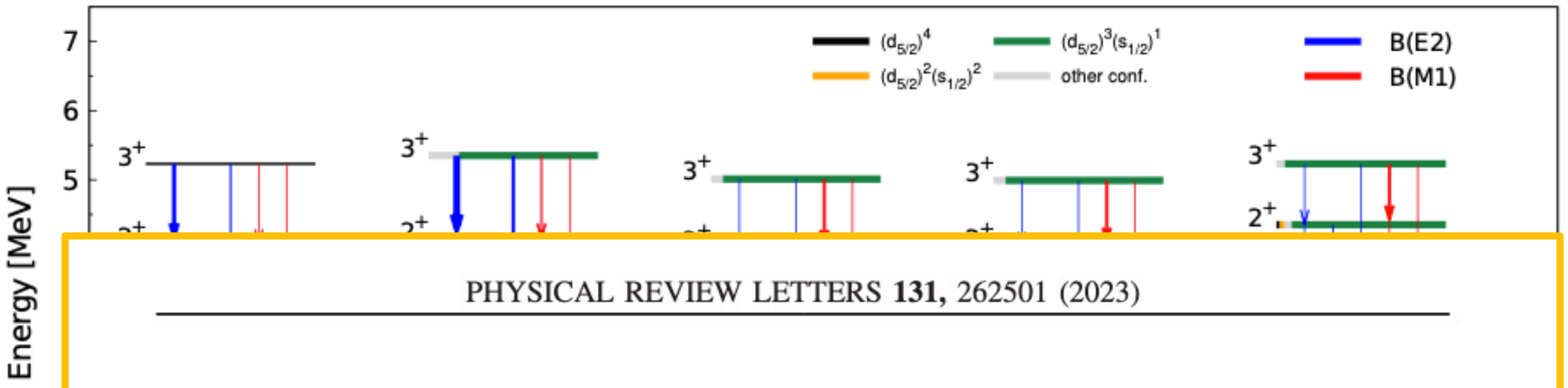
Part VI:
Theoretical interpretation

Comparison with theory

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



Comparison with theory



PHYSICAL REVIEW LETTERS **131**, 262501 (2023)

High-Precision Spectroscopy of ^{20}O Benchmarking *Ab Initio* Calculations in Light Nuclei

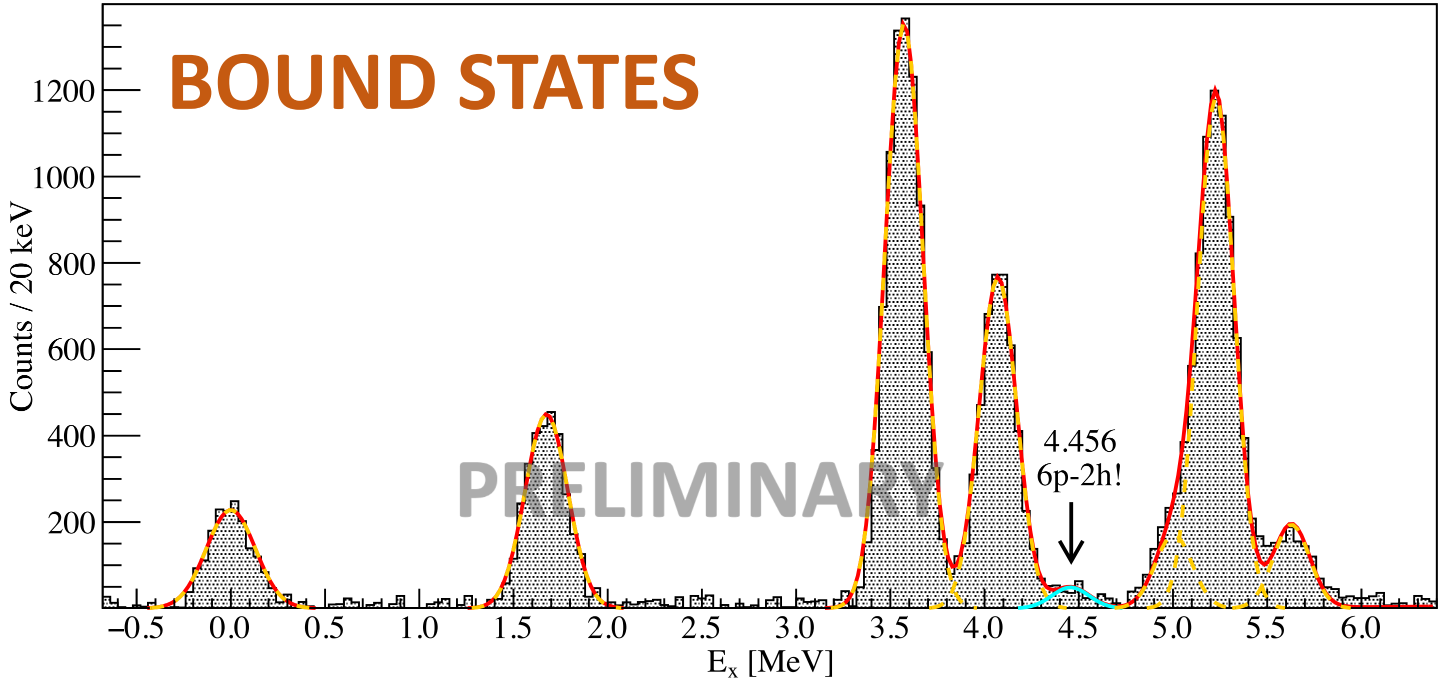
I. Zanon,[1,2,*] E. Clément,[3] A. Goasduff,[1] J. Menéndez,[4] T. Miyagi,[5,6,7] M. Assié,[8] M. Ciemała,[9] F. Flavigny,[10] A. Lemasson,[3] A. Matta,[10] D. Ramos,[3] M. Rejmund,[3] L. Achouri,[10] D. Ackermann,[3] D. Barrientos,[11] D. Beaumel,[8] G. Benzoni,[12] A. J. Boston,[13] H. C. Boston,[13] S. Bottoni,[14,12] A. Bracco,[12,14] D. Brugnara,[1,15] G. de France,[3] N. de Sereville,[8] F. Delaunay,[10] P. Desesquelles,[8] F. Didierjean,[16] C. Domingo-Prato,[17] J. Dudouet,[18] J. Eberth,[19] D. Fernández,[20] C. Fougères,[3] A. Gadea,[17] F. Galtarossa,[8] V. Girard-Alcindor,[3] V. Gonzales,[21] A. Gottardo,[1] F. Hammache,[8] L. J. Harkness-Brennan,[13] H. Hess,[19] D. S. Judson,[13] A. Jungclaus,[22] A. Kaşkaş,[23] Y. H. Kim,[24] A. Kuşoğlu,[25] M. Labiche,[26] S. Leblond,[3] C. Lenain,[10] S. M. Lenzi,[27] S. Leoni,[12] H. Li,[3] J. Ljungvall,[8] J. Lois-Fuentes,[20] A. Lopez-Martens,[8] A. Maj,[28] R. Menegazzo,[27] D. Mengoni,[15,27] C. Michelagnoli,[3,24] B. Million,[12] D. R. Napoli,[1] J. Nyberg,[29] G. Pasqualato,[15,27] Zs. Podolyak,[30] A. Pullia,[12] B. Quintana,[31] F. Recchia,[15,27] D. Regueira-Castro,[20] P. Reiter,[19] K. Rezynkina,[32] J. S. Rojo,[33] M. D. Salsac,[34] E. Sanchis,[21] M. Şenyiğit,[23] M. Siciliano,[34,35] D. Sohler,[36] O. Stezowski,[18] Ch. Theisen,[34] A. Utepov,[3,10] J. J. Valiente-Dobón,[1] D. Verney,[8] and M. Zielinska[34]

Underestimation of B(E2)

Role of the B(M1) in the comparison

Nature of the 2^+_1 state more complex

Part VII:
Future perspective



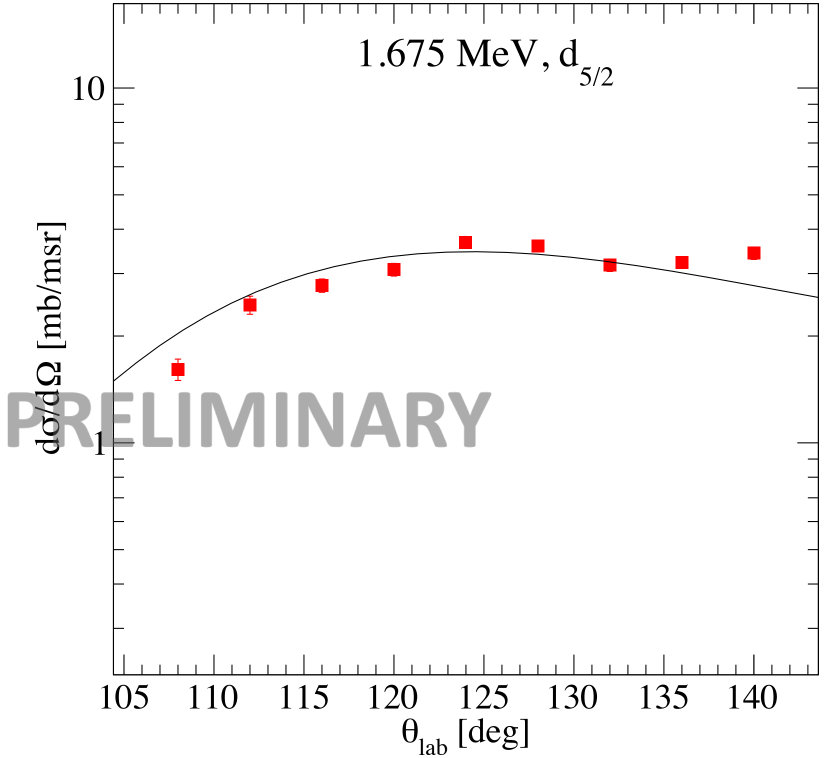
Next steps:

- Normalisation of angular distrib.
- Extract **spectroscopic factors**
- **High-E γ-rays**, from unbound?
- Limit on the lifetime of high-energy states

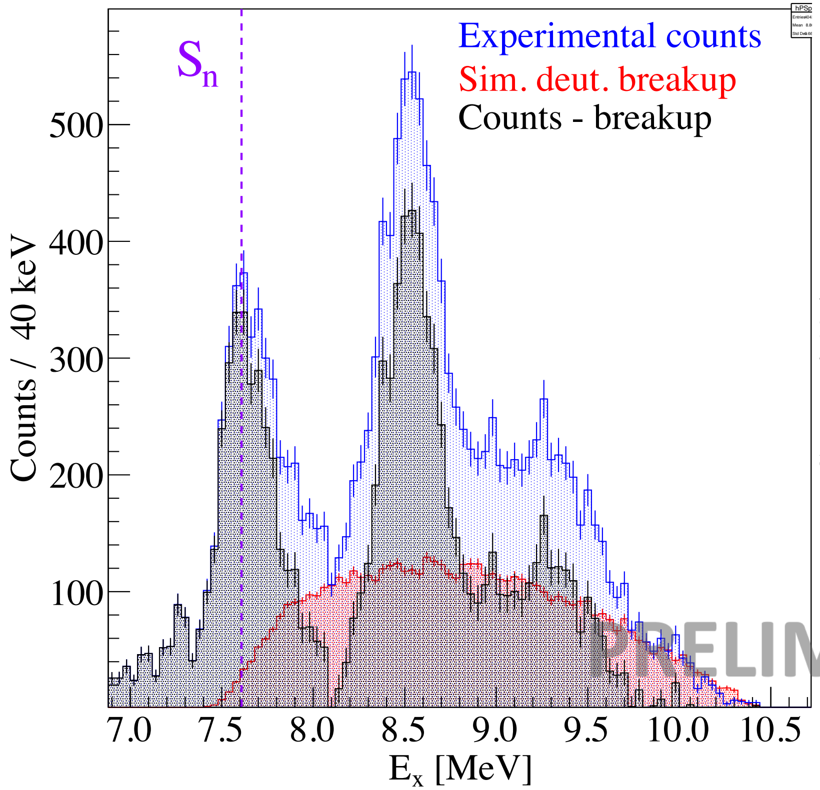
Courtesy of C. Paxman, post-doc @ GANIL

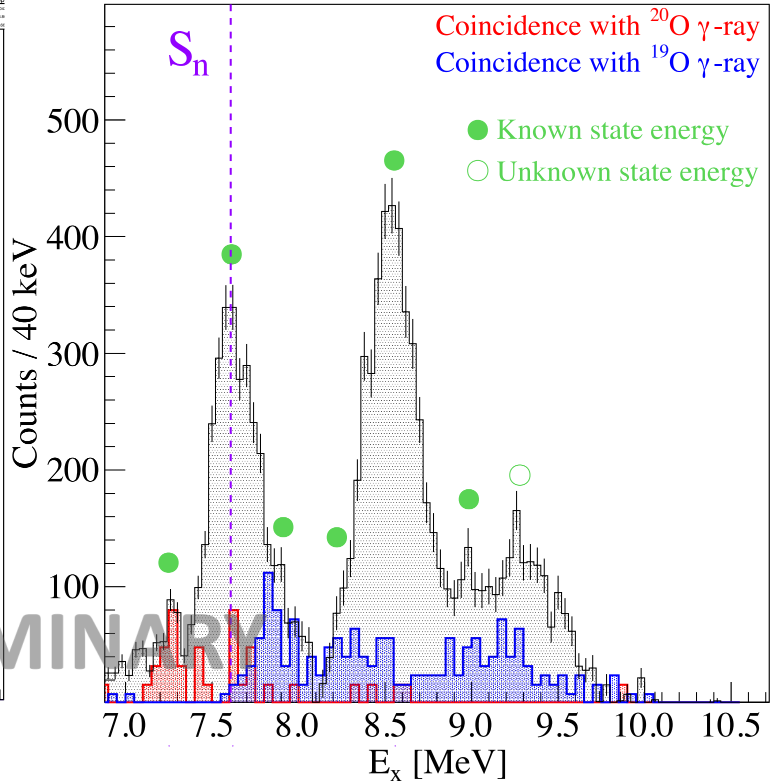
So far:

◊ Tweaks: σ = 98 keV @ 5.3 MeV
◊ **Angular distributions** extracted
◊ Compared to **optical models**



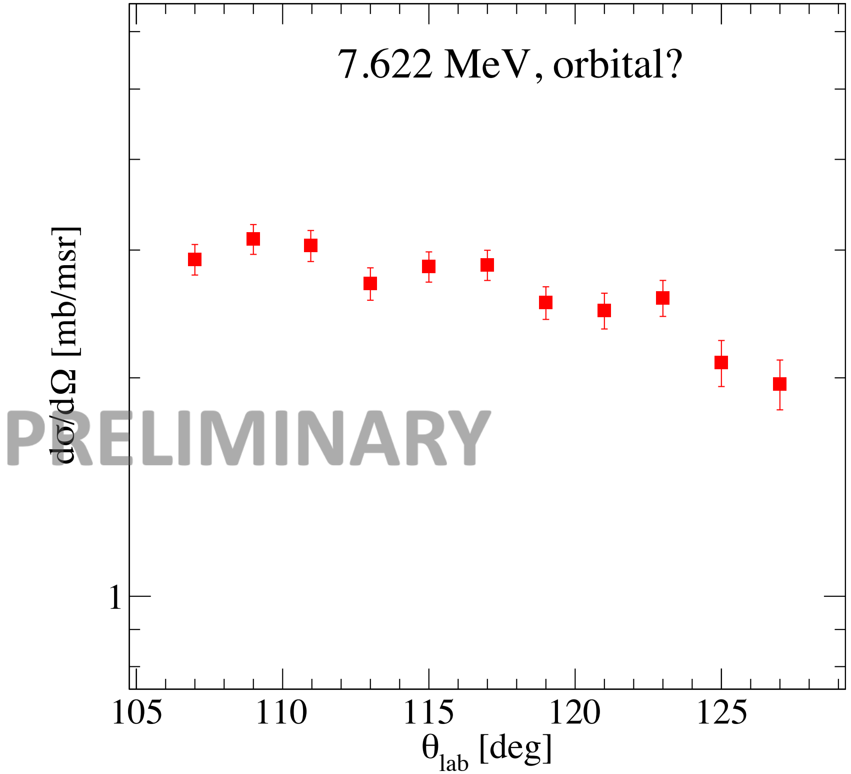
UNBOUND STATES





So far:

- Simul. deuteron breakup subtracted
- γ-ray coinc., several unbound states
  - ◆ Energies from ^{18}O(t,p) & ^{20}N(β^-)
- **Angular distributions** extrated



Challenges:

◇ **Optical model reliability** over Sn?

Courtesy of C. Paxman, post-doc @ GANIL

Conclusions

- Challenging experiment with state-of-the art particle detection and γ-ray tracking;
- Precise control on the population of the states using of (d,p) reaction to populate ^{20}O;
- Lifetime measurement of the 2^+_2 and 3^+_1 states;
- Importance of mp-mh excitation and B(M1);

Thank you for your attention

The collaboration

<u>I.Zanon</u>, E. Clément, C. Paxman, A. Goasduff, J. Menendez, T. Miyagi, M. Ciemała, M. Assié, F. Flavigny, C. Fougeres, S. Leblond, A. Lemasson, A. Matta, D. Ramos, K. Rezynkina, 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 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. Utepov, Y.H. Kim, M. Zielinska

On behalf of the AGATA, VAMOS and MUGAST collaborations

Publications

Experiment e775s:

- I. Zanon et al., High-Precision Spectroscopy of ^{20}O Benchmarking Ab Initio Calculations in Light Nuclei,
  Physical Review Letter 131, 262501 (2023)
- D. Mengoni et al., Advances in nuclear structure via charged particle reactions with AGATA
  Eur. Phys. J A **59(5)**, 117 (2023)
- M. Assié *et al.*, The MUGAST-AGATA-VAMOS campaign,
  NIM A **1014** 165743 (2021);

- I. Zanon, Testing three-body forces in the oxygen region via lifetime measurements,
  NC **45 C** 66 (2022);
- I. Zanon, Lifetime measurements in ^{20}O via DSAM,
  NC **44 C** 83 (2021);