



PROBING THE STRUCTURAL EVOLUTION IN NEON ISOTOPES APPROACHING THE $N = 20$ ISLAND OF INVERSION

EXP_015 / EXP_032 / EXP_058

Davide Genna
University of Milan, INFN Milan

26th AGATA Week and ACC meeting – September 8th



D. Genna^[1,2], F. Drent^[3], K. Wimmer^[3,4], S. Bottoni^[1,2], P. Aguilera^[5], G. Benzoni^[2],
F. Recchia^[6,7], G. Andreetta^[6,7], F. Angelini^[3], M. Balogh^[8], J. Bardak^[3,9], J. Benito^[10],
B. Bles^[3,9], A. Bracco^[1,2], D. Brugnara^[10], S. Carollo^[6,7], Z. Chen^[3], F. Conca^[1,2], L. Corradi^[10],
G. Corbari^[1,2], F. C. L. Crespi^[1,2], M. del Fabbro^[11], A. Ertoprak^[6,7], E. Fioretto^[10], F. Galtarossa^[6],
A. Giaz^[2], A. Goasduff^[10], B. Gongora Servin^[10], A. Gottardo^[10], Gozzelino^[10], B. Greaves^[10],
A. Jungclaus^[12], T. Kröll^[8], G. Kosir^[13], S. Leoni^[1,2], M. Luciani^[1,2], R. Menegazzo^[7], D. Mengoni^[6,7],
B. Million^[2], G. Montagnoli^[7], R. Nicolás del Álamo^[6,7], J. Pellumaj^[6,7], R. Pérez-Vidal^[14],
S. Pigliapoco^[15], E. Pilotto^[10], W. Poklepa^[3], M. Polettini^[3,16], K. Rezynekina^[6,7], M. Rocchini^[17],
E. Ronning^[10], M. Sedlak^[8], F. Simioni^[6,7], A. Stefanini^[7], A. Togni^[6,7], J. J. Valiente-Dobón^[14],
J. Vesic^[13], L. Zago^[18], I. Zanon^[19].

[1] Dipartimento di Fisica, Università degli Studi di Milano, Italy

[2] INFN Sezione di Milano, Italy

[3] GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany

[4] University of Cologne, Germany

[5] Comisión Chilena de Energía Nuclear (CCHEN), Chile

[6] Dipartimento di Fisica, Università degli Studi di Padova, Italy

[7] INFN Sezione di Padova, Italy

[8] Institute of Physics of the Slovak Academy of Sciences, Slovakia

[9] University of Novi Sad, Serbia

[10] Istituto Nazionale di Fisica Nucleare LNL, Legnaro, Italy

[11] Ruđer Bošković Institute, Croatia

[12] CSIC Madrid, Spain

[13] Jožef Stefan Institute, Slovenia

[14] IFIC Universitat de València, Spain

[15] Grand Accélérateur National d'Ions Lourds, France

[16] Facility for Antiproton and Ion Research in Europe GmbH (FAIR GmbH), Germany

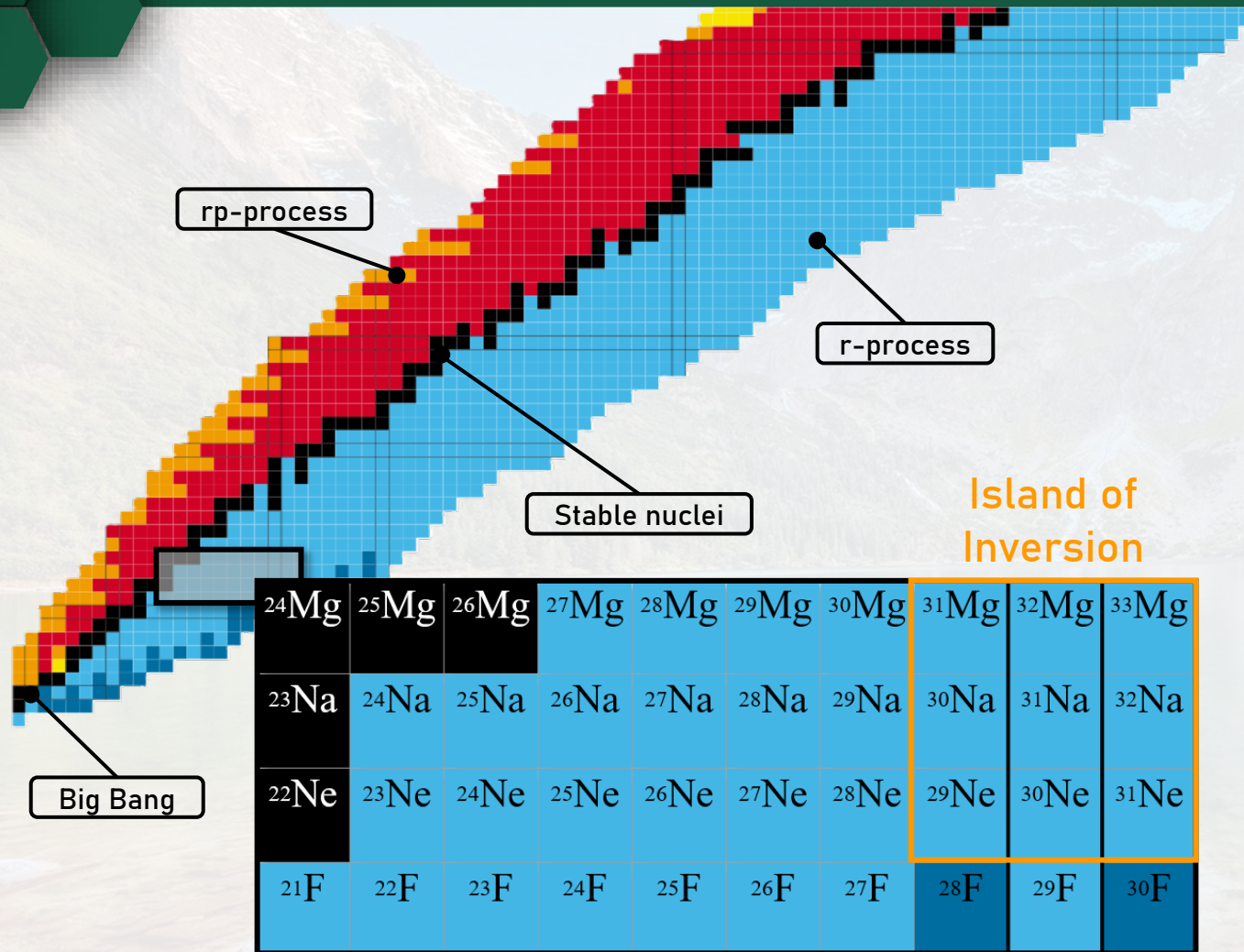
[17] INFN Sezione di Firenze, Italy

[18] Institut de Physique des Deux Infinis de Lyon, France

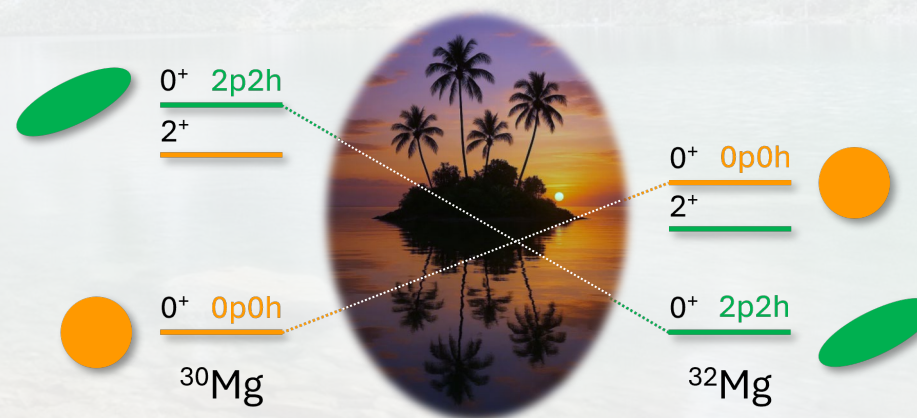
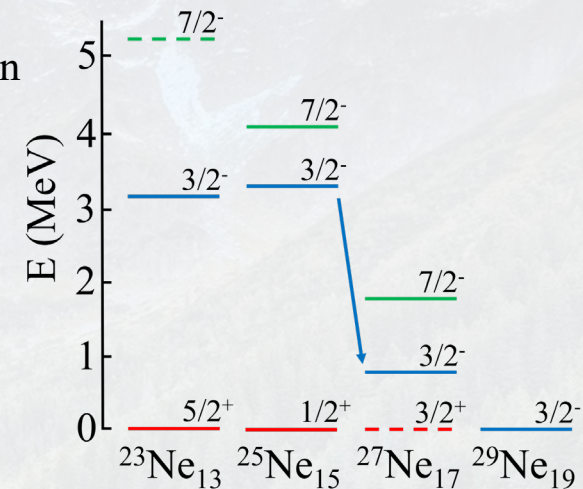
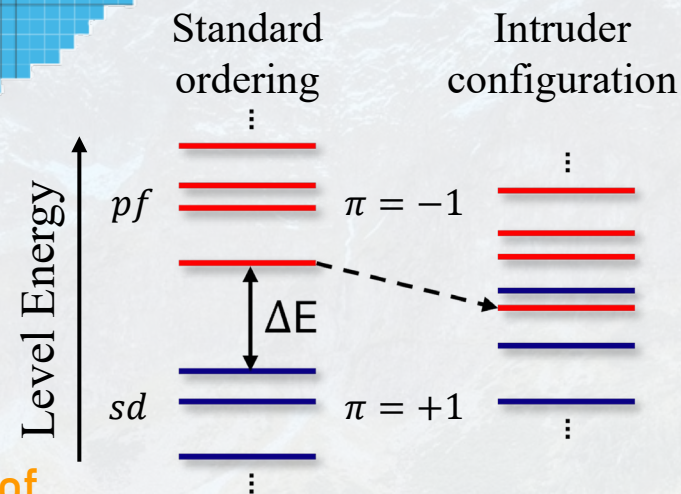
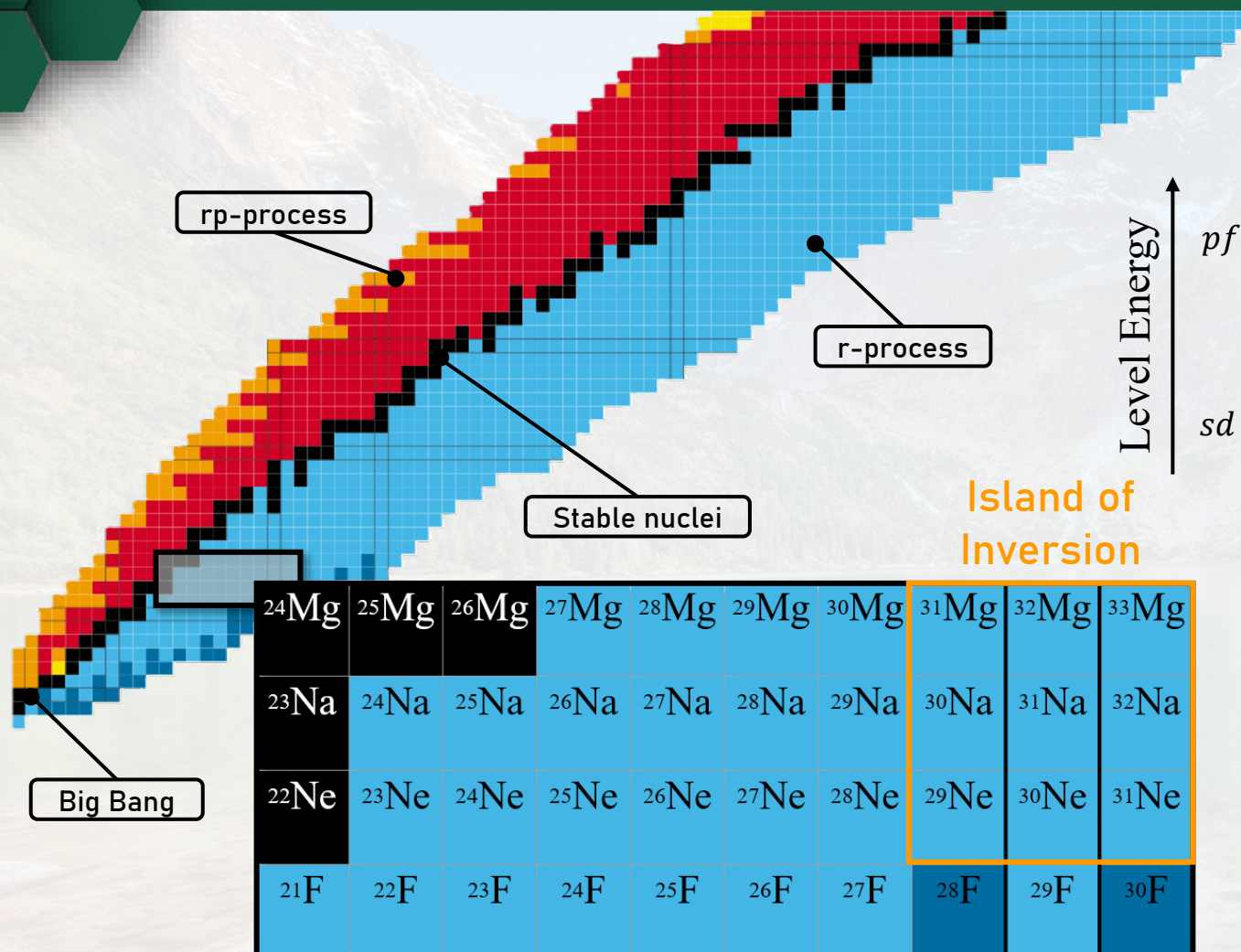
[19] KTH Royal Institute of Technology, Sweden

26th AGATA Week and ACC meeting – September 8th

The N = 20 Island of Inversion

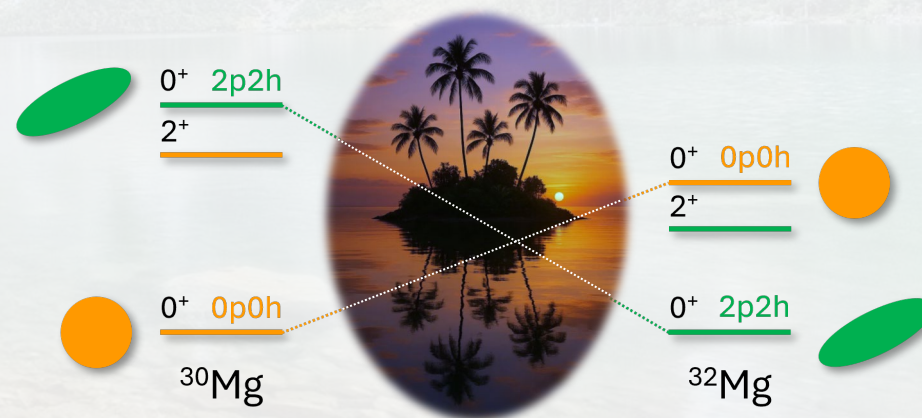
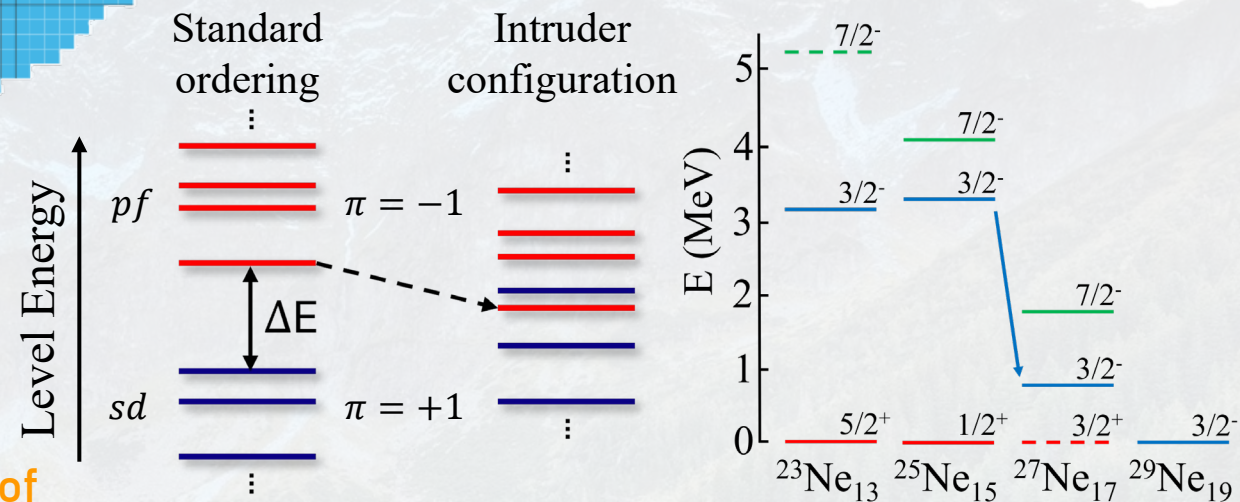
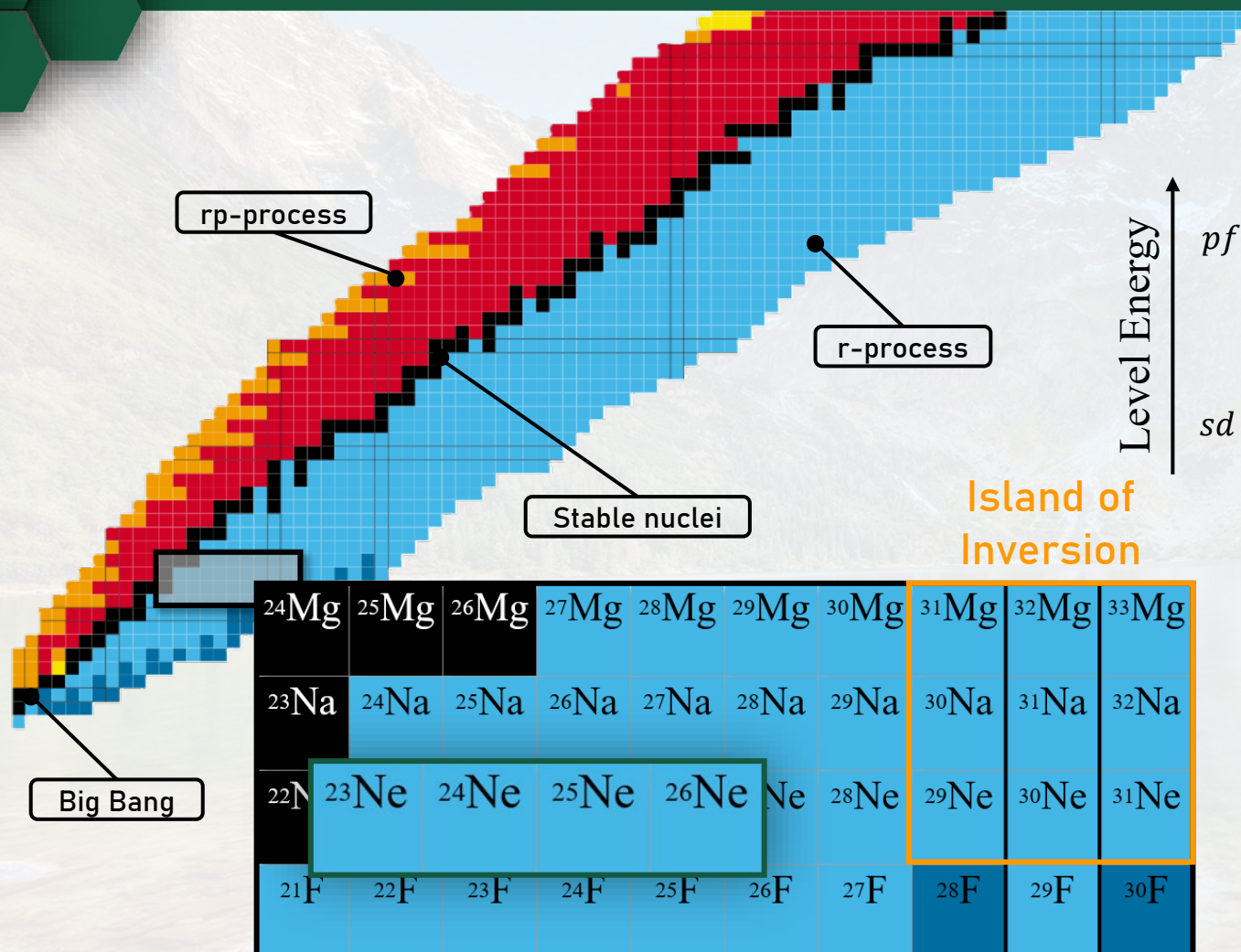


The N = 20 Island of Inversion



Adapted from K. Wimmer et al., Phys. Rev. Lett. 105 252501 2010

The N = 20 Island of Inversion



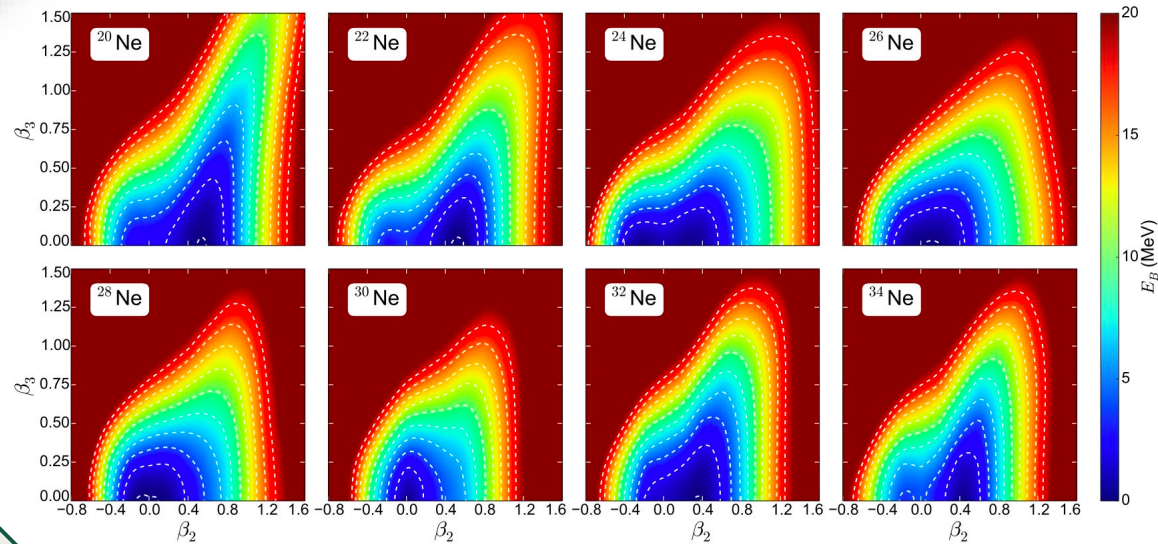
Adapted from K. Wimmer et al., Phys. Rev. Lett. 105 252501 2010

Spectroscopy and lifetime measurements for n-rich Ne isotopes
Validation for different theoretical models

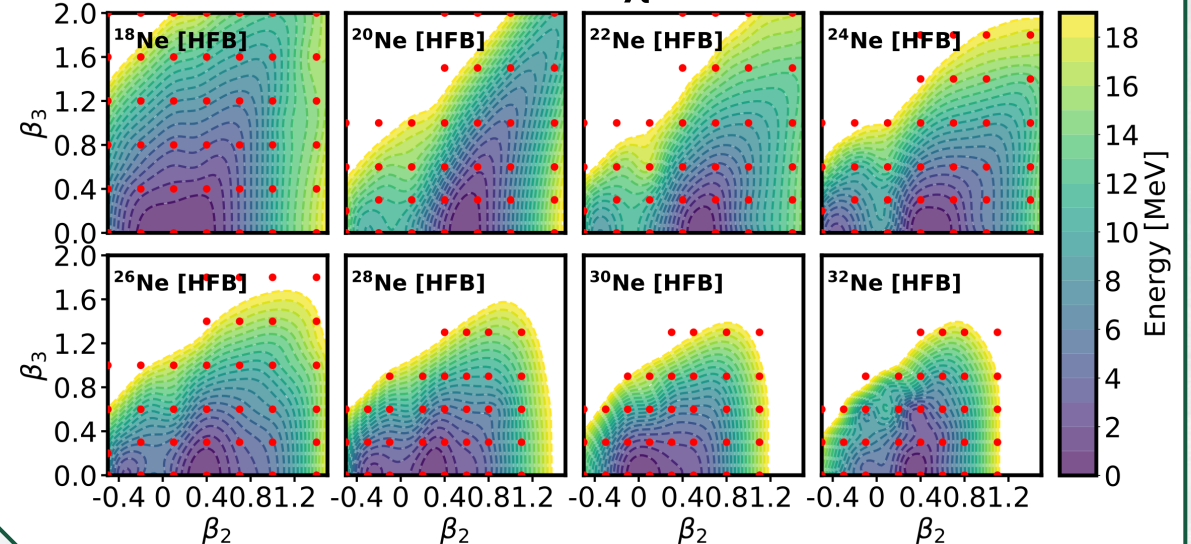
DFT and ab initio calculations

RHB: Physical Review C 97 024334 2018
PGCM, IN-NCSM: The European Physical Journal A 58:63 2022

Relativistic HFB



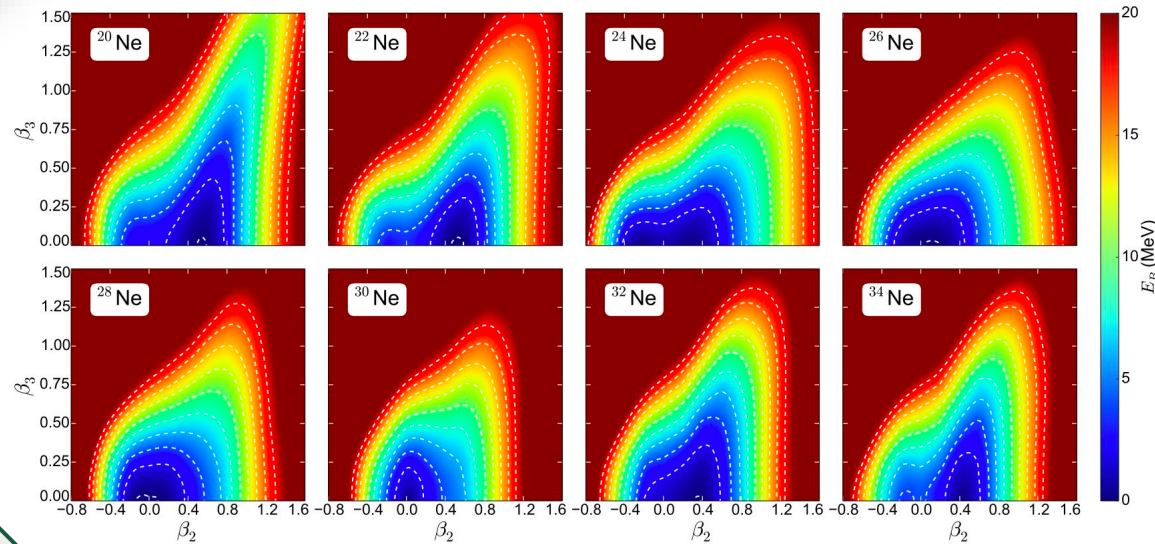
PGCM & IN-NCSM on χEFT Hamiltonians



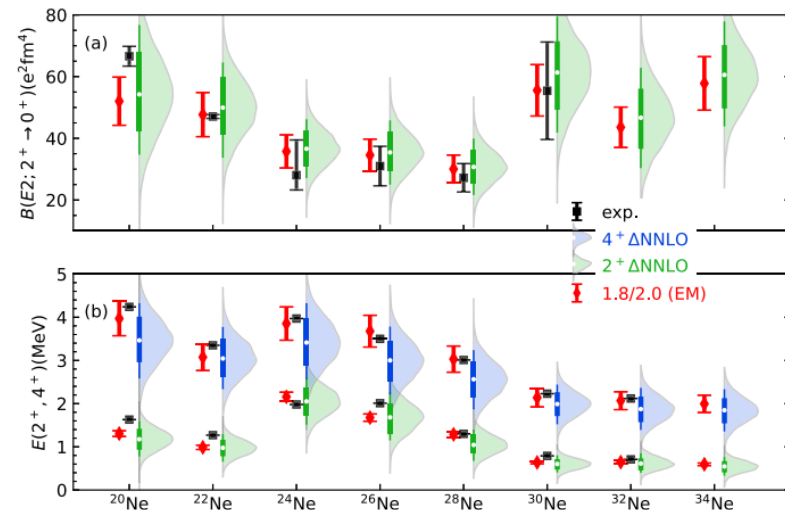
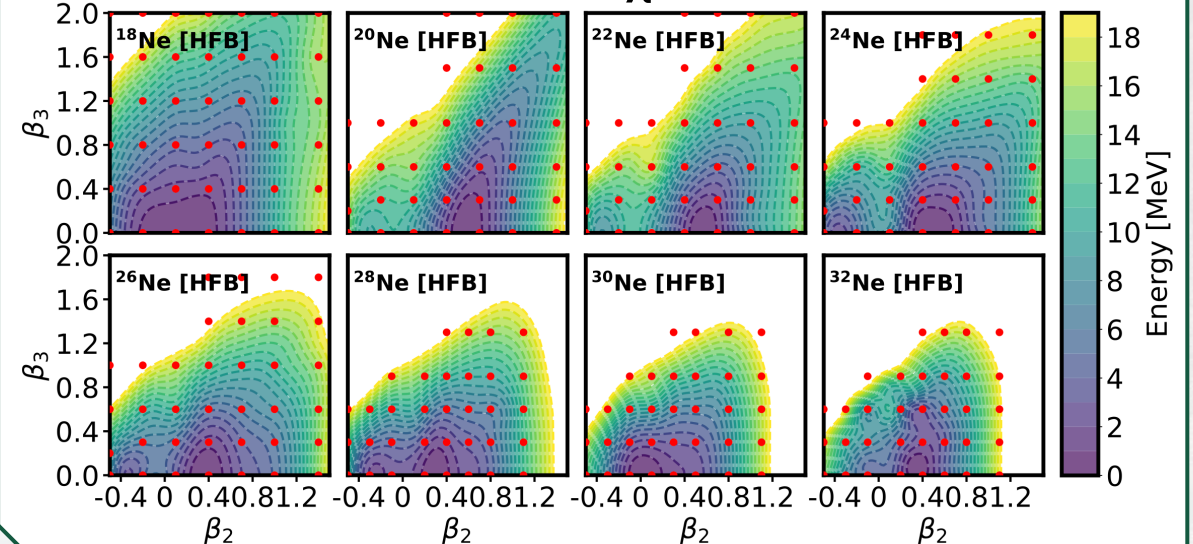
DFT and ab initio calculations

RHB: Physical Review C 97 024334 2018
 PGCM, IN-NCSM: The European Physical Journal A 58:63 2022
 CC: Physical Review C 111 044304 2025
 CC: Physical Review X 15 011028 2025

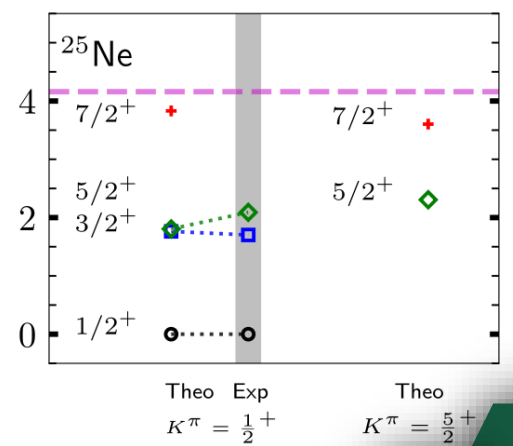
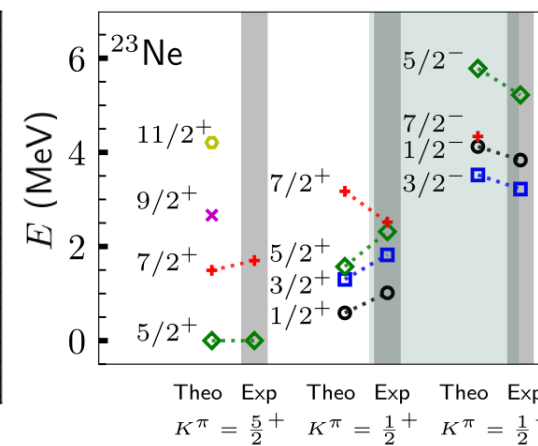
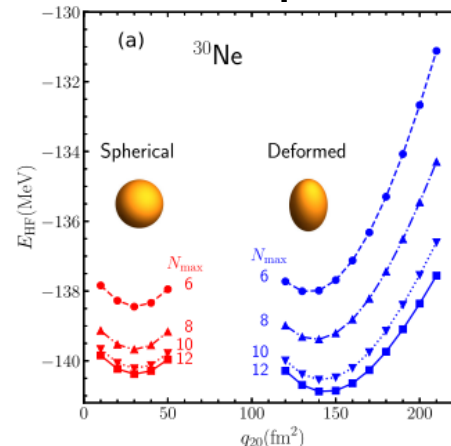
Relativistic HFB



PGCM & IN-NCSM on χ EFT Hamiltonians



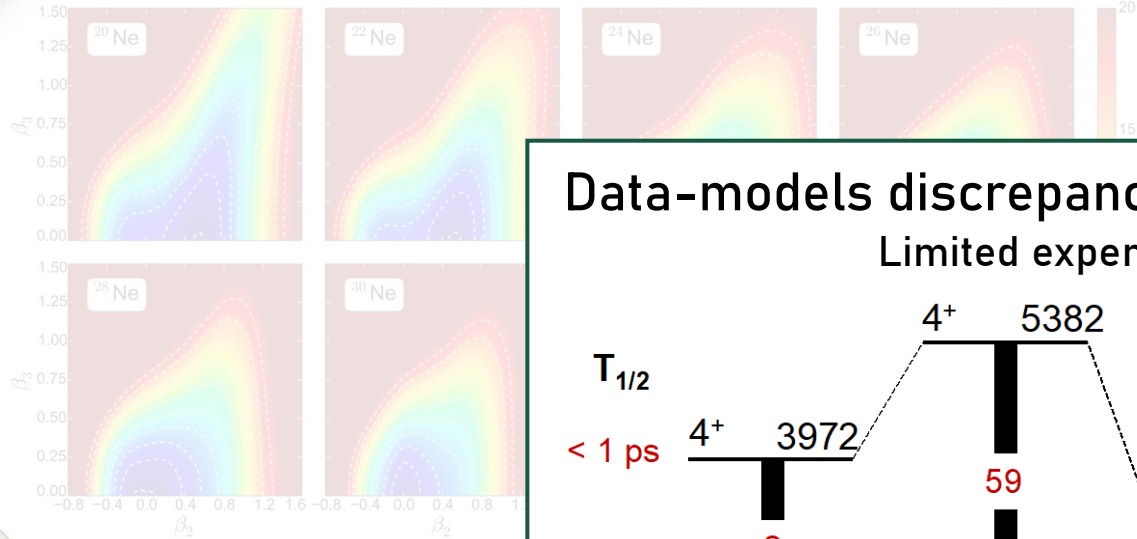
Coupled Cluster



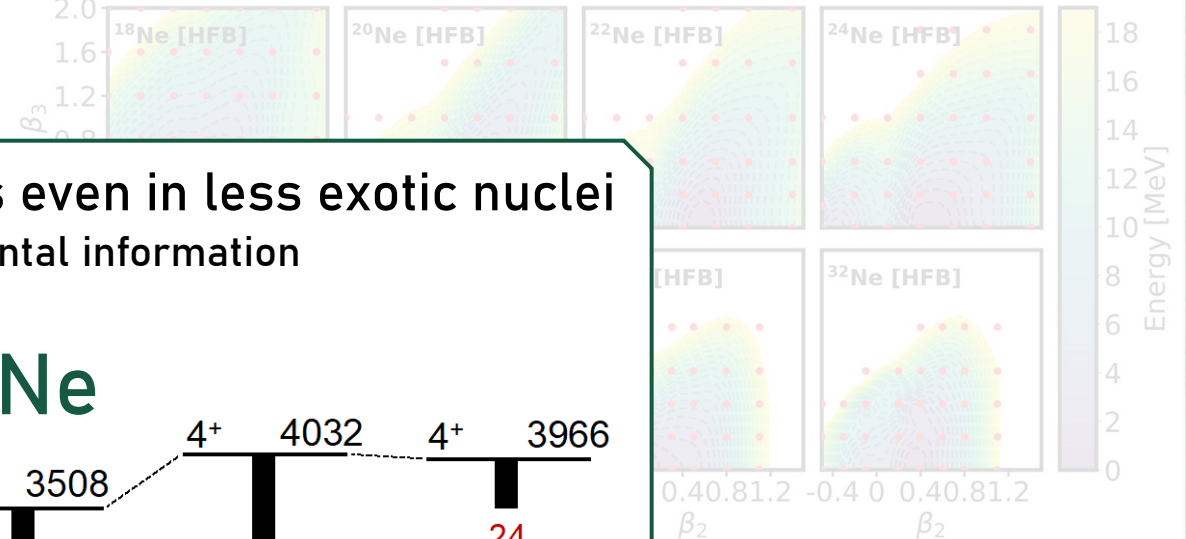
DFT and ab initio calculations

RHB: Physical Review C 97 024334 2018
PGCM, IN-NCSM: The European Physical Journal A 58:63 2022
CC: Physical Review C 111 044304 2025
CC: Physical Review X 15 011028 2025

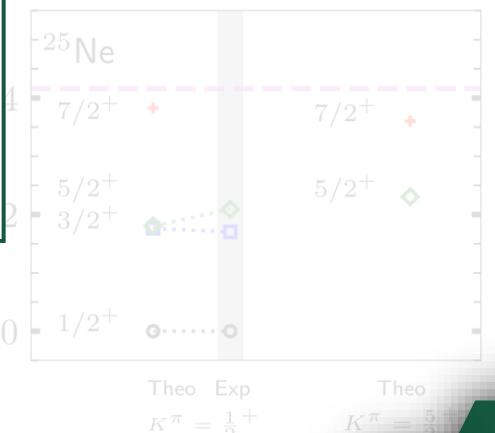
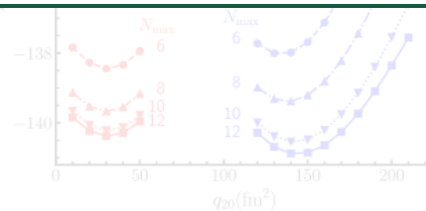
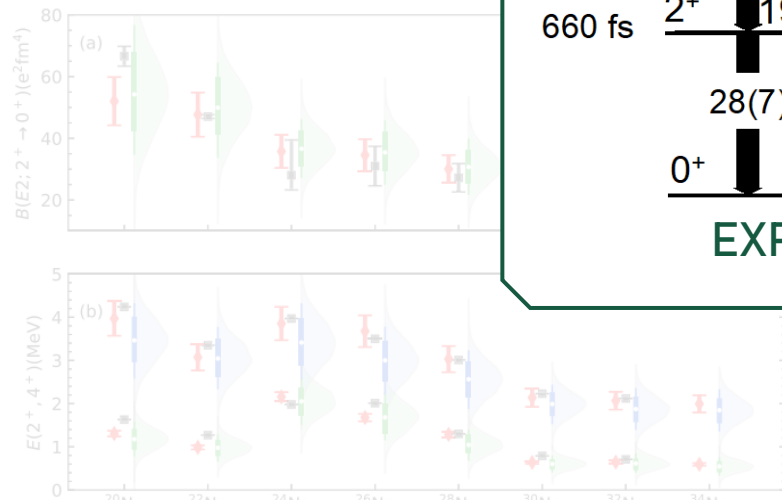
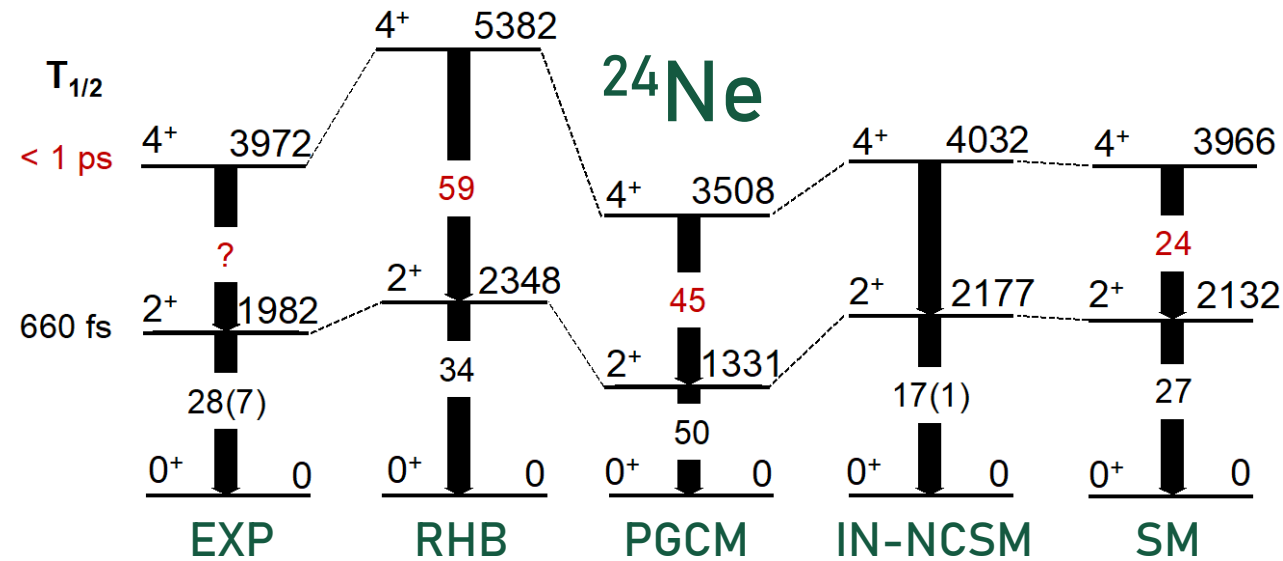
Relativistic HFB



PGCM & IN-NCSM on χ EFT Hamiltonians

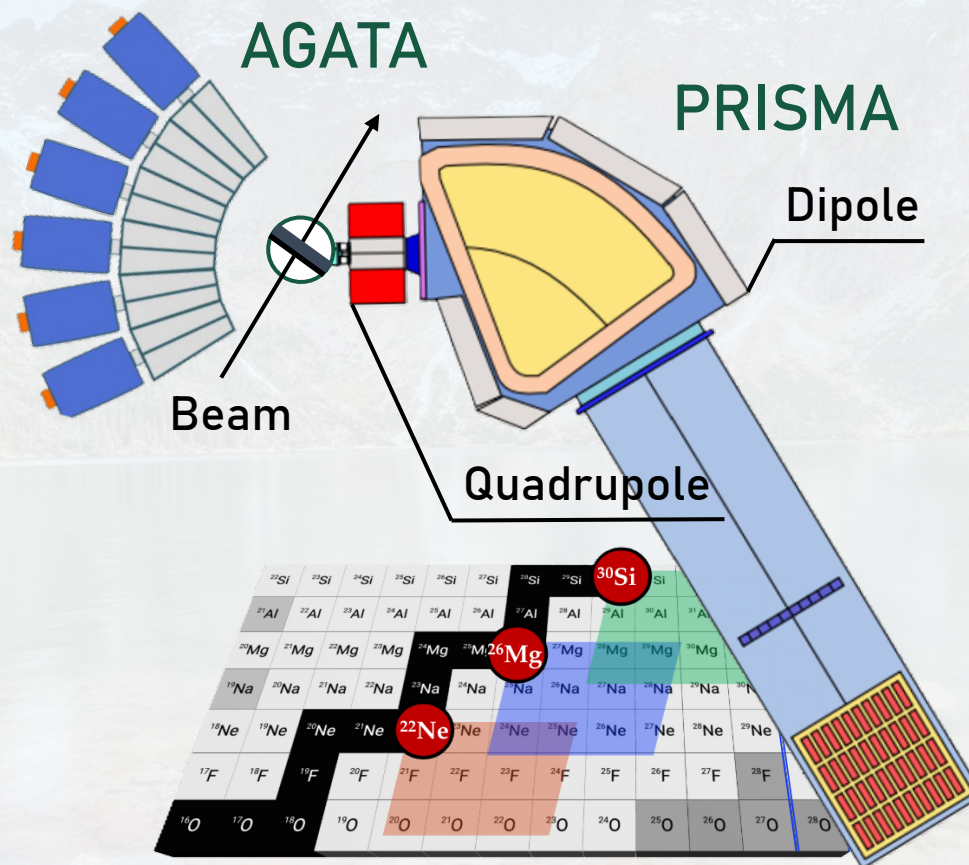


Data-models discrepancies even in less exotic nuclei Limited experimental information



The experimental campaign

Multi-nucleon transfer reactions @LNL
AGATA-PRISMA with ^{238}U target



European Physical Journal Plus 138:709 2023

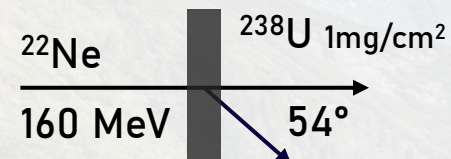
Spectroscopy and lifetimes based
on clean ion- γ coincidences

The experimental campaign

Multi-nucleon transfer reactions @LNL AGATA-PRISMA with ^{238}U target

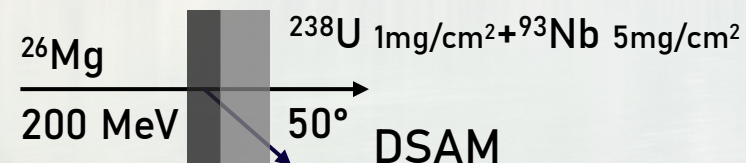
April 2023: $^{22}\text{Ne} + ^{238}\text{U}$

Spectroscopy



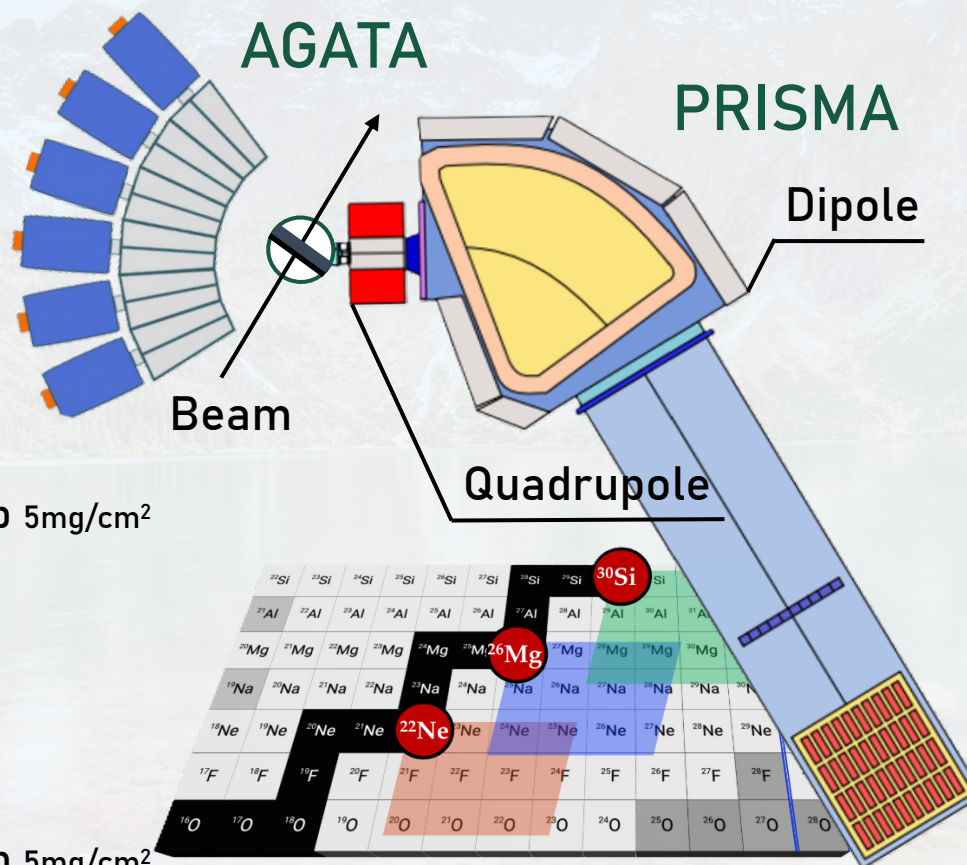
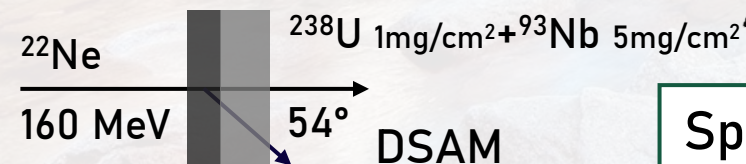
June 2024: $^{26}\text{Mg} + ^{238}\text{U}$

Lifetime Measurements



May 2026: $^{22}\text{Ne} + ^{238}\text{U}$

Lifetime Measurements



European Physical Journal Plus 138:709 2023

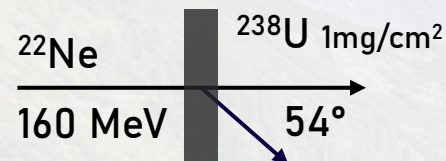
Spectroscopy and lifetimes based
on clean ion- γ coincidences

The experimental campaign

Multi-nucleon transfer reactions @LNL AGATA-PRISMA with ^{238}U target

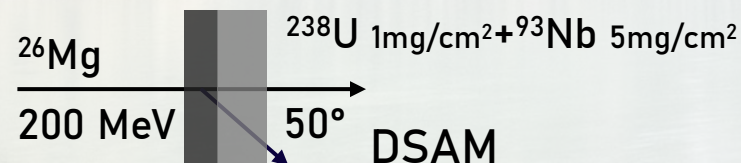
April 2023: $^{22}\text{Ne} + ^{238}\text{U}$

Spectroscopy



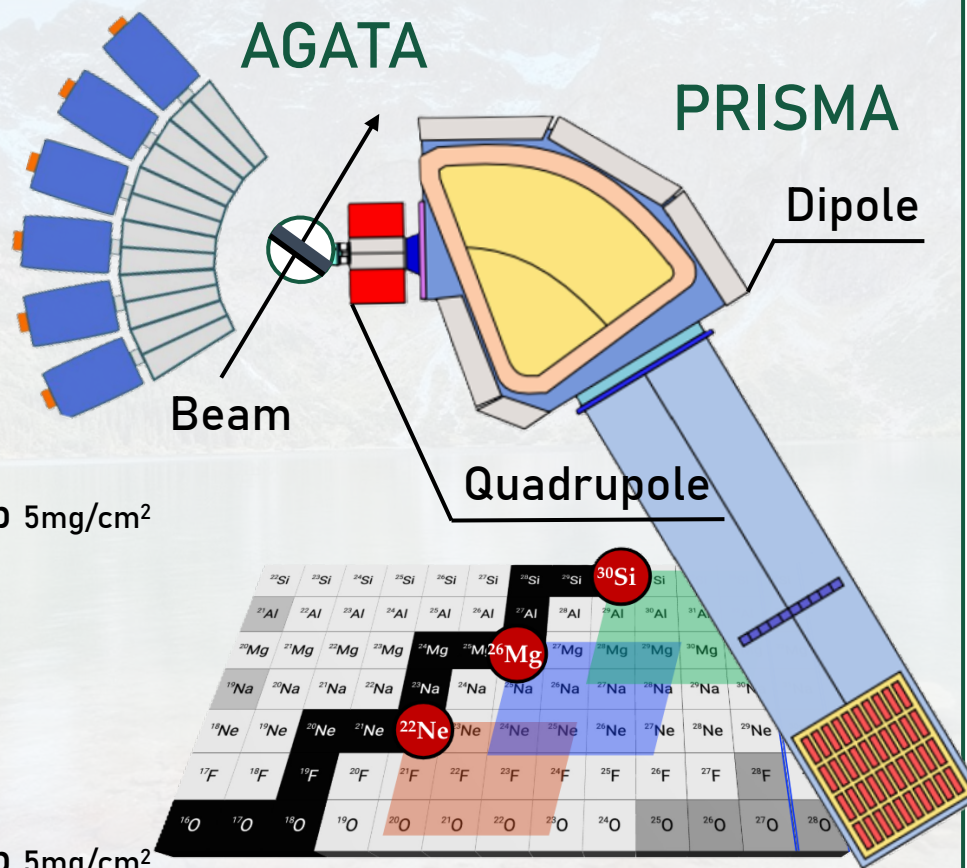
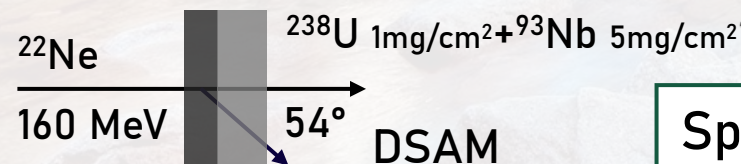
June 2024: $^{26}\text{Mg} + ^{238}\text{U}$

Lifetime Measurements



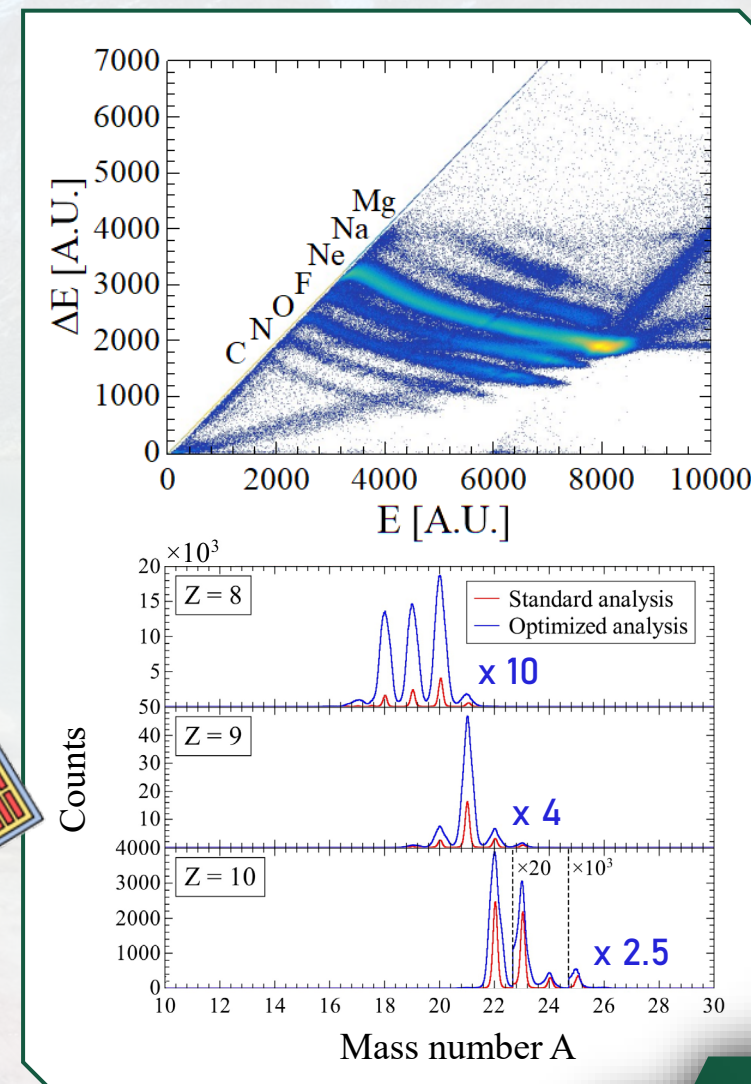
May 2026: $^{22}\text{Ne} + ^{238}\text{U}$

Lifetime Measurements



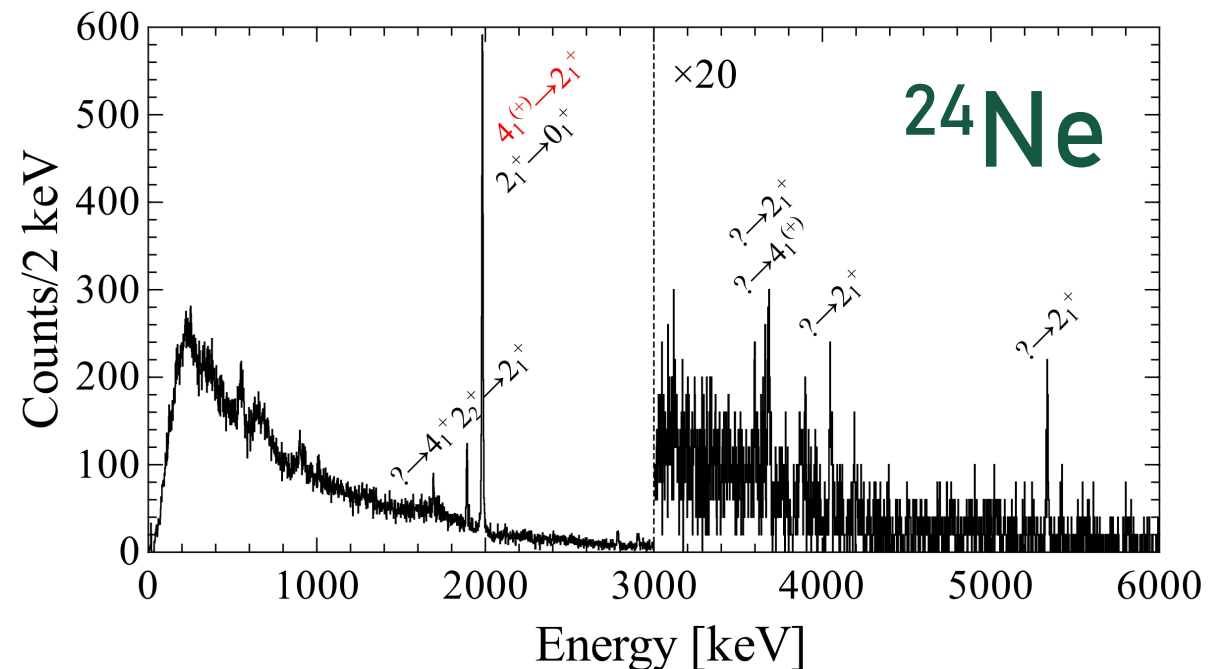
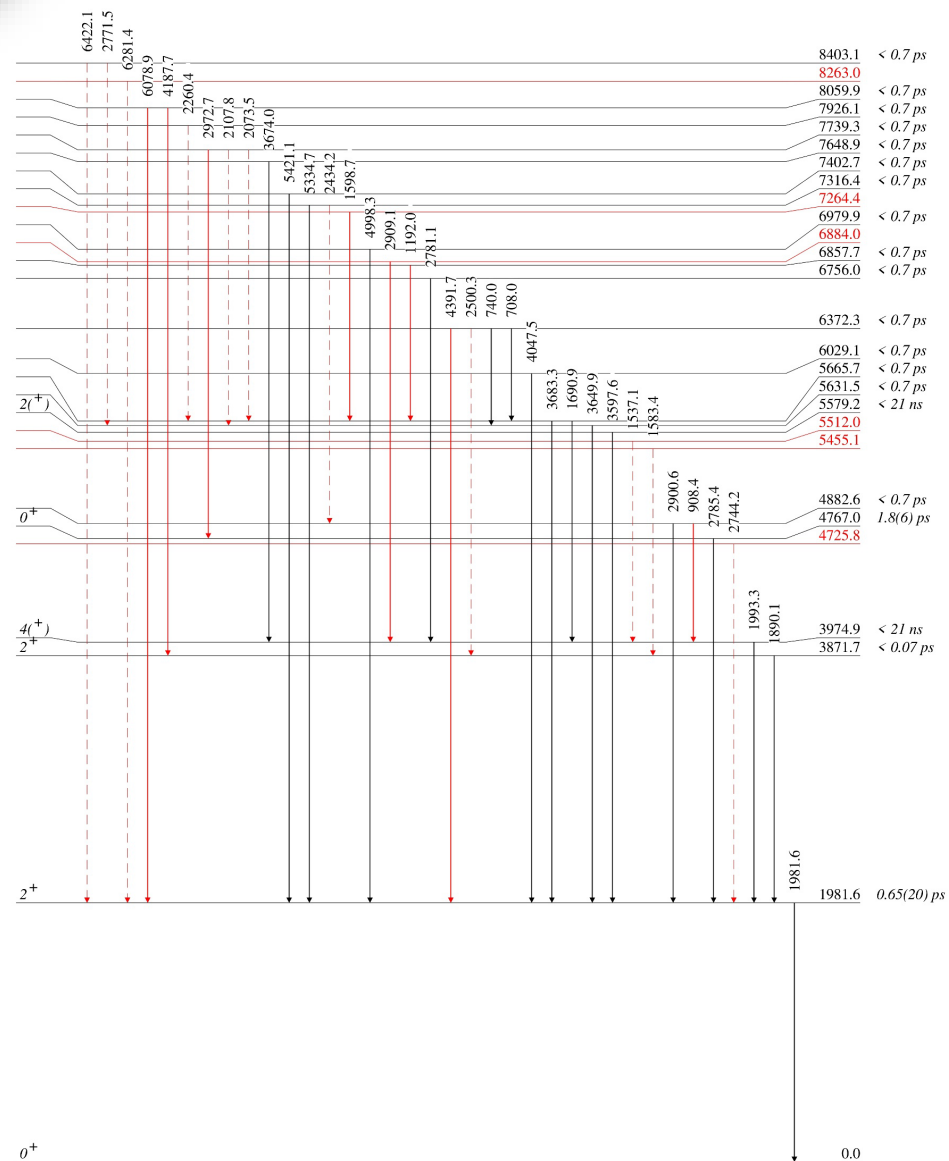
European Physical Journal Plus 138:709 2023

Spectroscopy and lifetimes based
on clean ion- γ coincidences

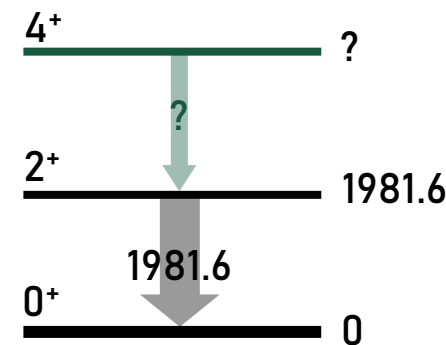


Results: Ne level schemes

Spectroscopy



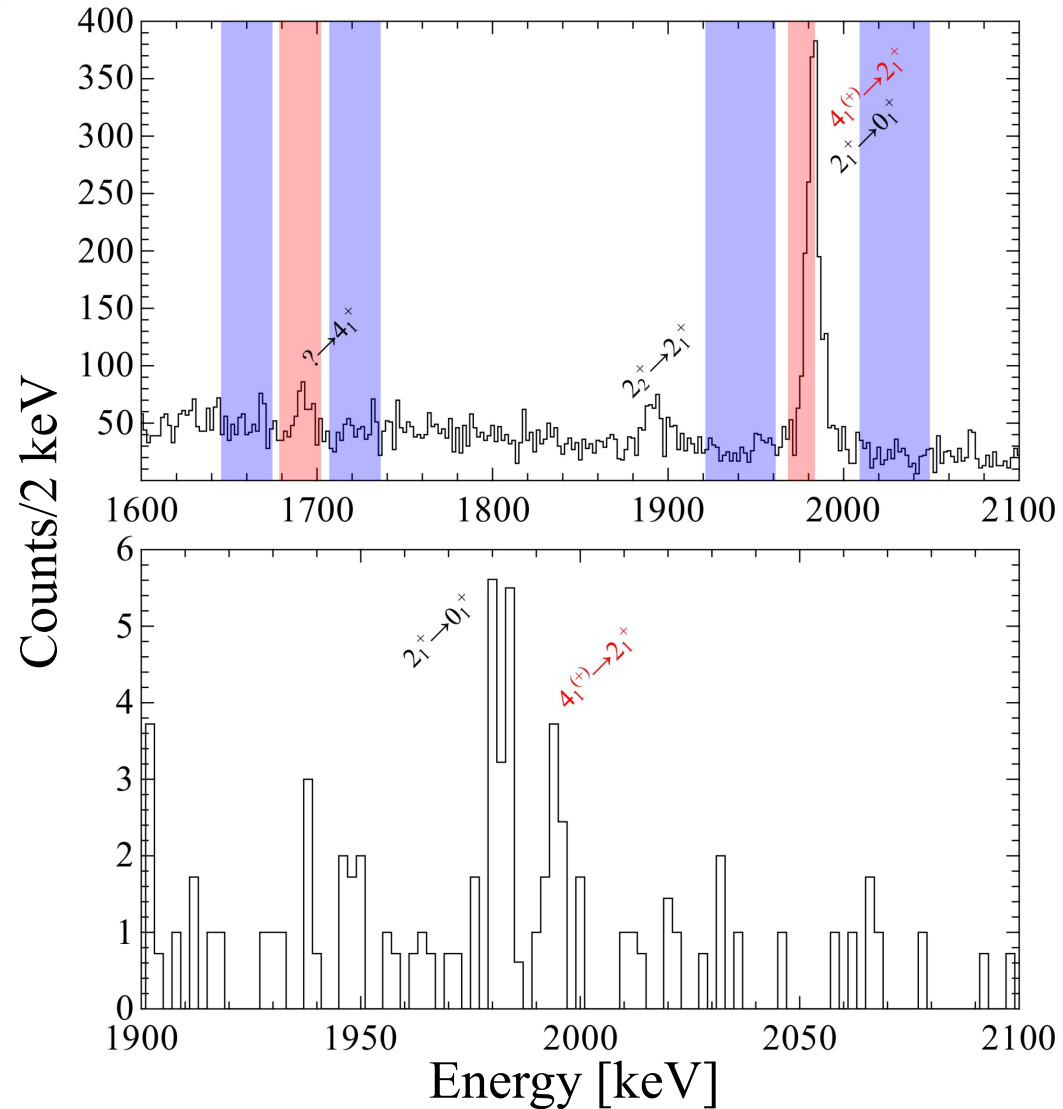
- 6 new levels added
- 8 (+11 uncertain) new observed transitions
- Focus on low energy doublet structure: 2_1^+ and 4_1^+ states



Results: ^{24}Ne energy doublet

Spectroscopy

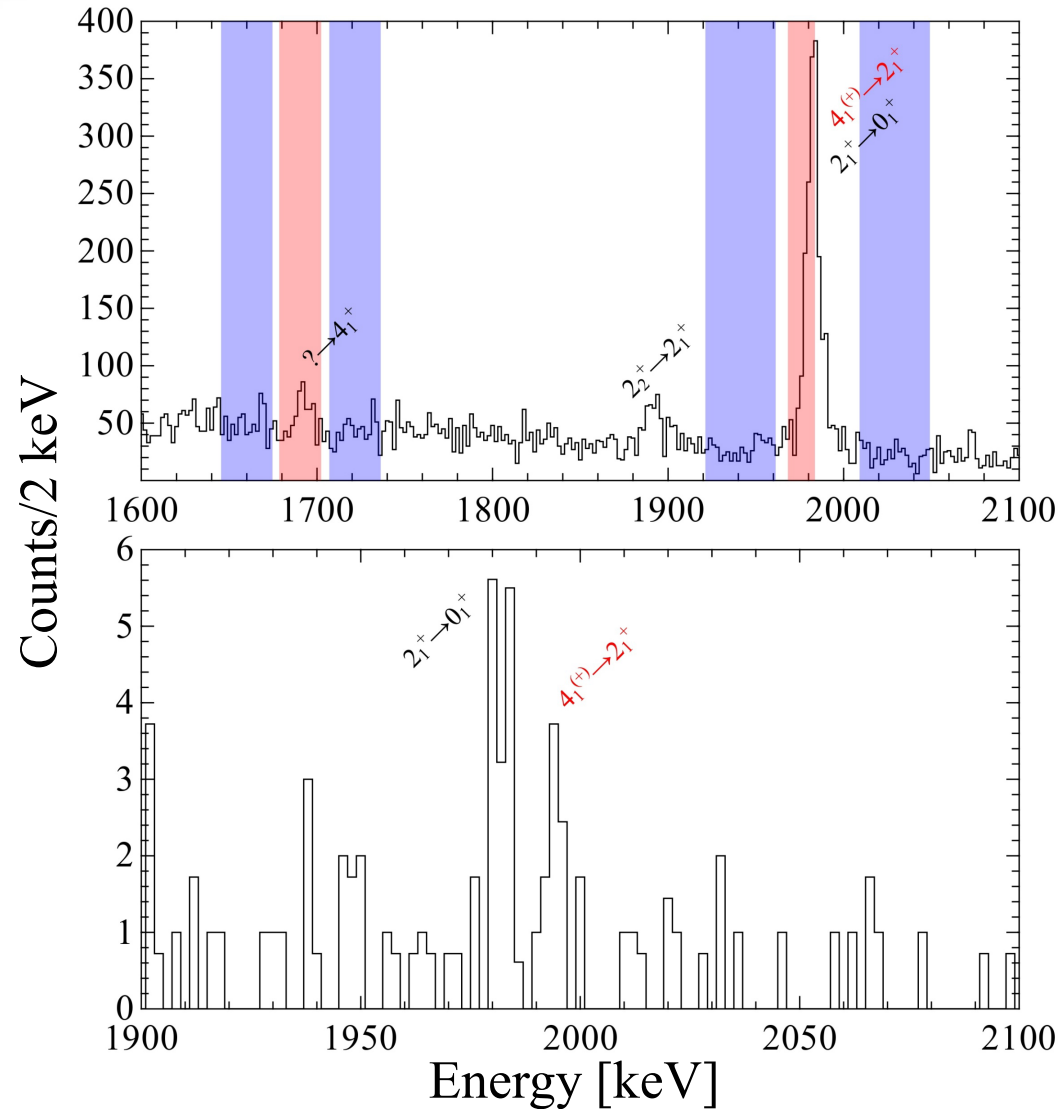
$\gamma - \gamma$ Coincidence Matrix



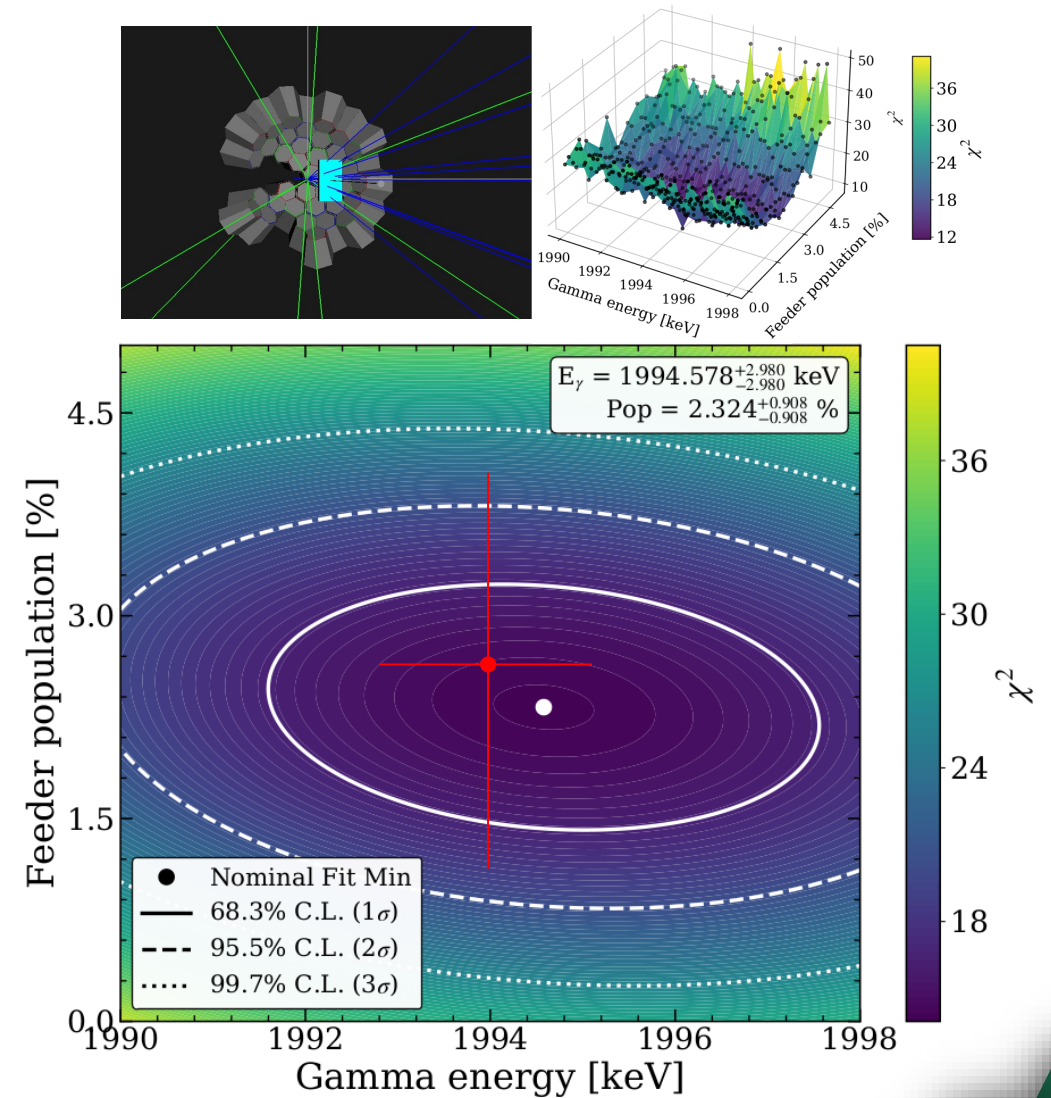
Results: ^{24}Ne energy doublet

Spectroscopy

$\gamma - \gamma$ Coincidence Matrix



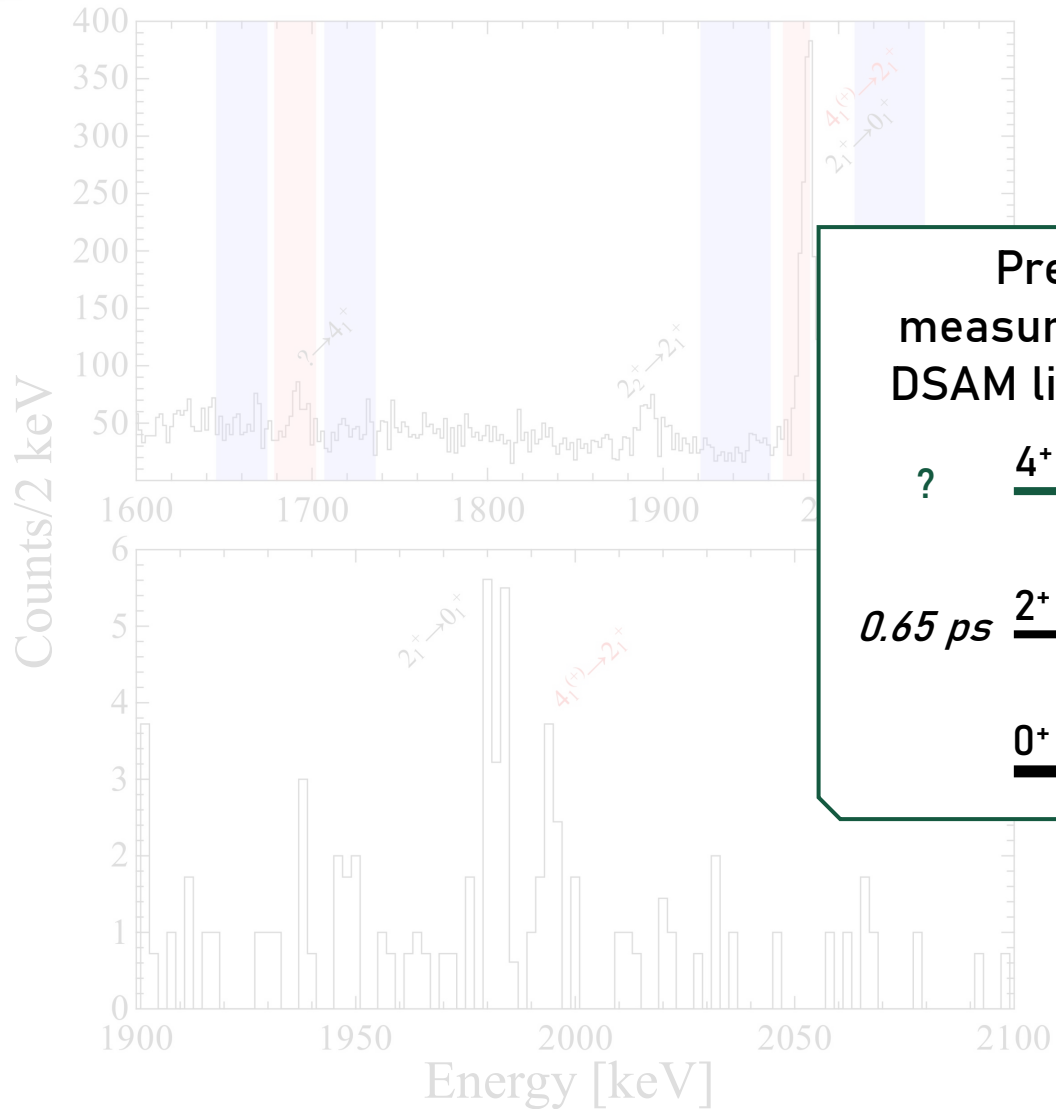
AGATA Simulations (Geant4)



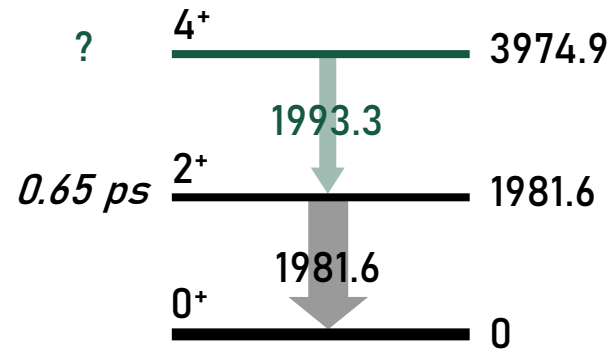
Results: ^{24}Ne energy doublet

Spectroscopy

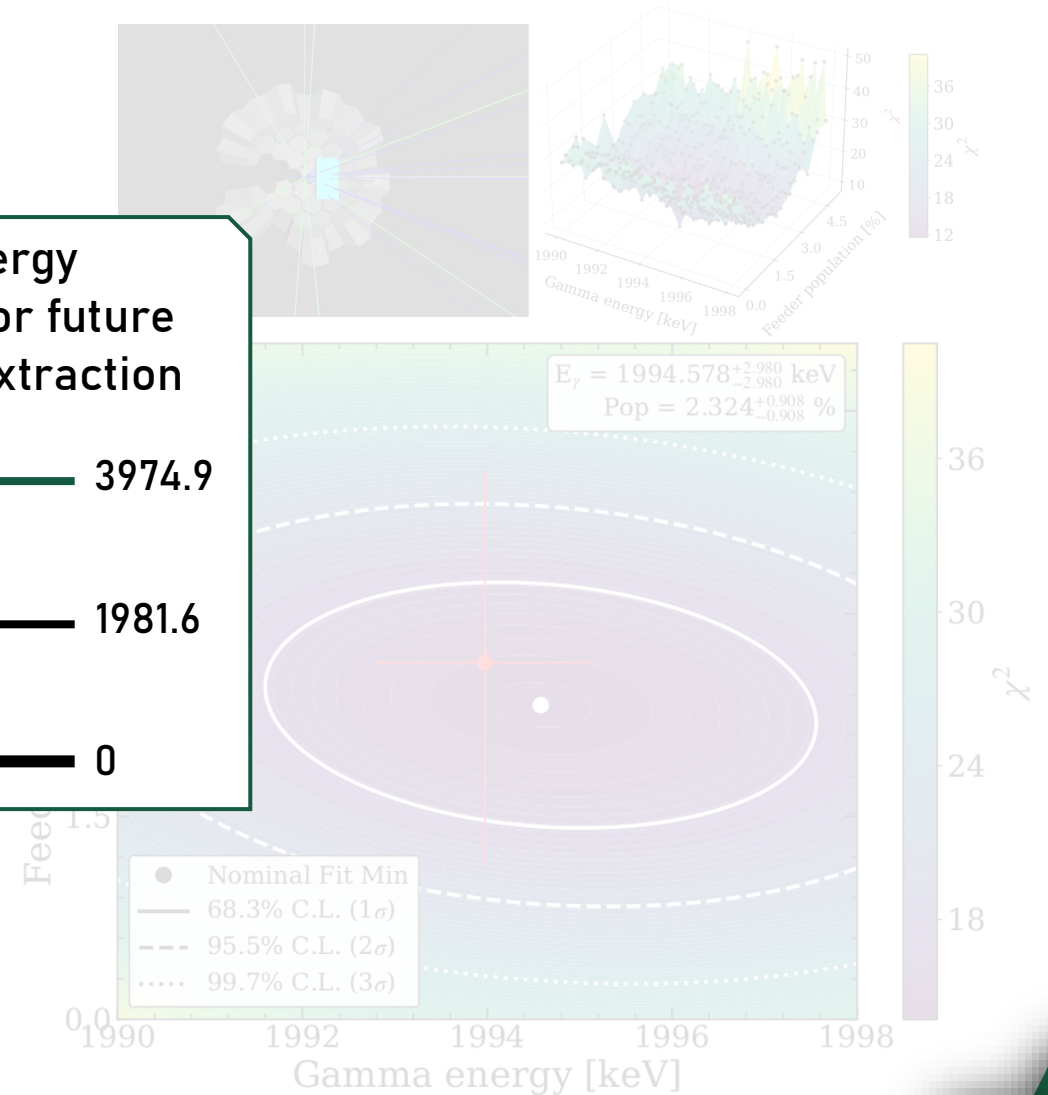
$\gamma - \gamma$ Coincidence Matrix



Precise energy
measurement for future
DSAM lifetime extraction

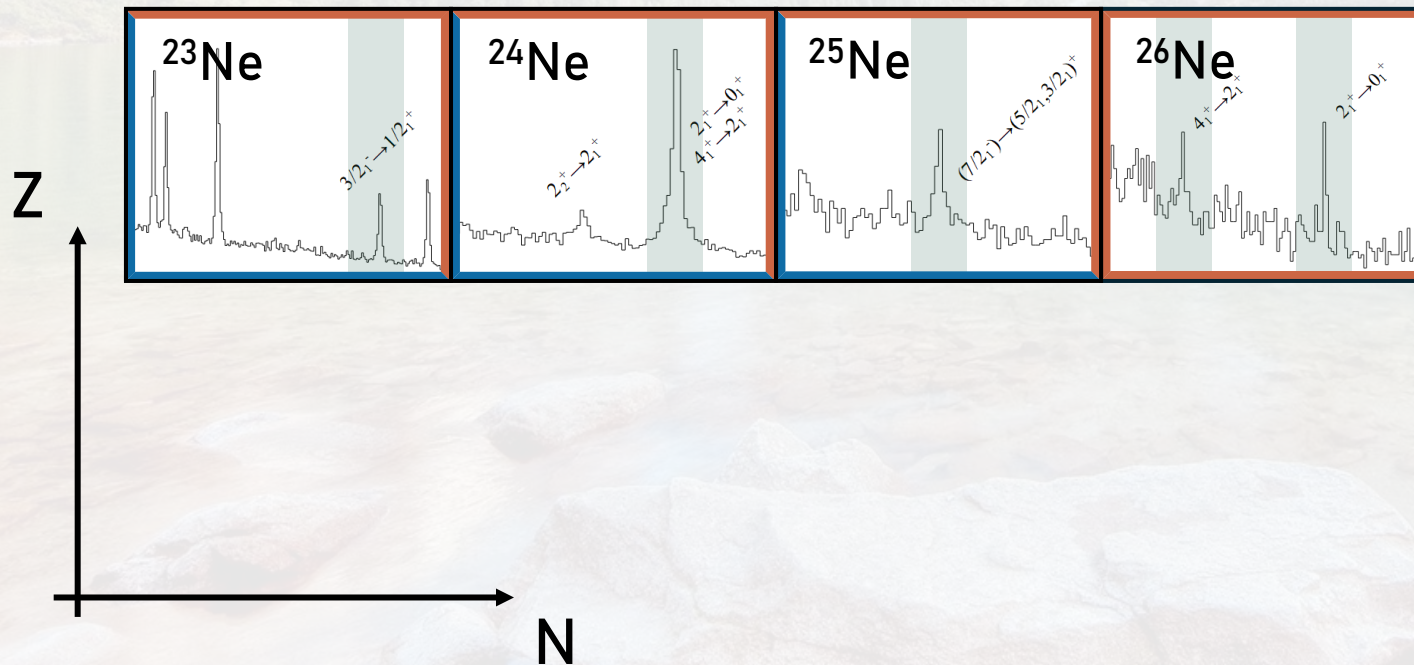


AGATA Simulations (Geant4)



Outlook and perspectives

- Rotational band collectivity in $^{24,26}\text{Ne}$
- Intruder states in $^{23,25}\text{Ne}$



April 2023: $^{22}\text{Ne} + ^{238}\text{U}$

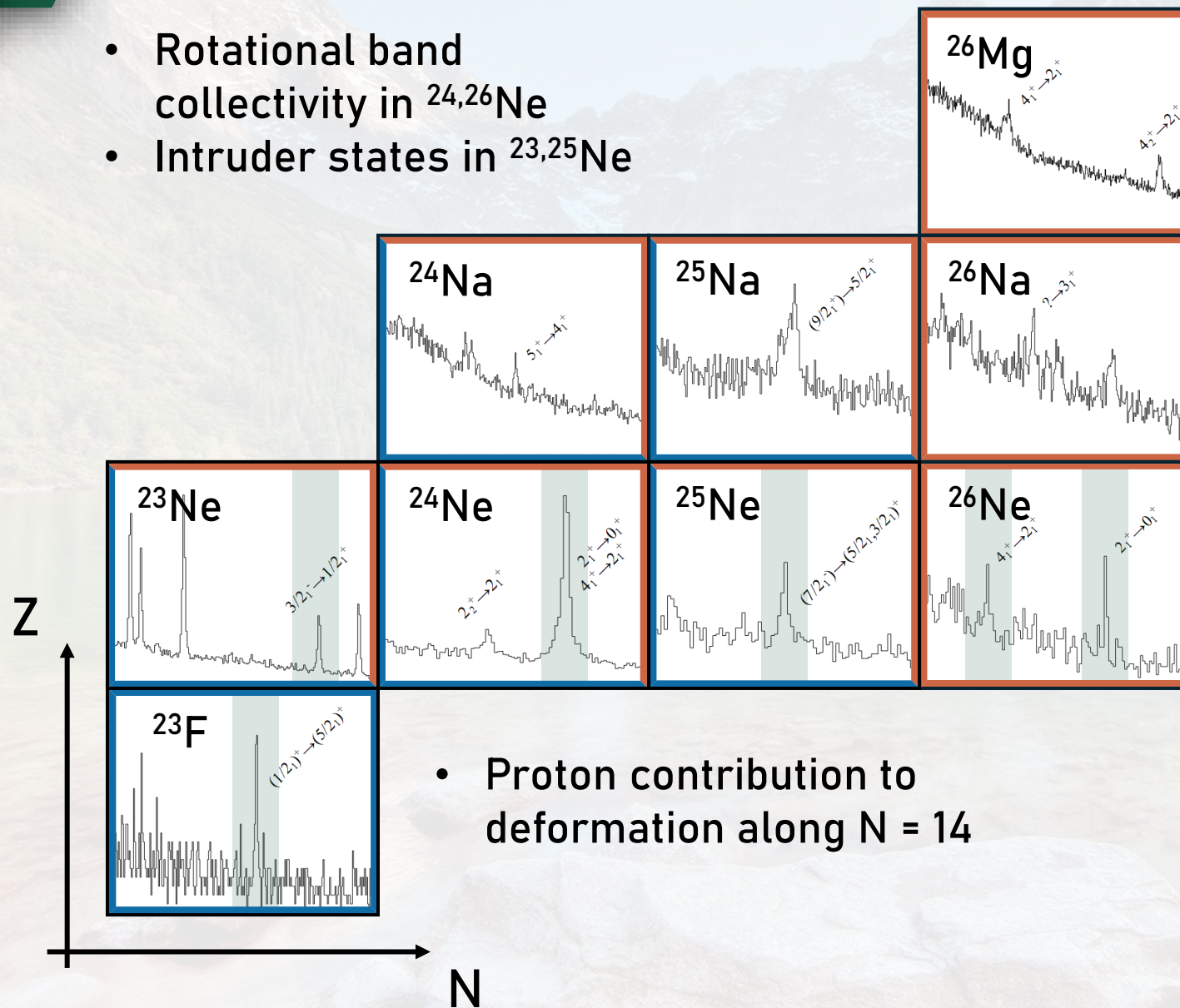
June 2024: $^{26}\text{Mg} + ^{238}\text{U}$

Pre-analysis by F. Drent (GSI)

May 2026: $^{22}\text{Ne} + ^{238}\text{U}$

Outlook and perspectives

- Rotational band collectivity in $^{24,26}\text{Ne}$
- Intruder states in $^{23,25}\text{Ne}$



- Exotic Mg isotopes toward the Island of Inversion

April 2023: $^{22}\text{Ne} + ^{238}\text{U}$

June 2024: $^{26}\text{Mg} + ^{238}\text{U}$

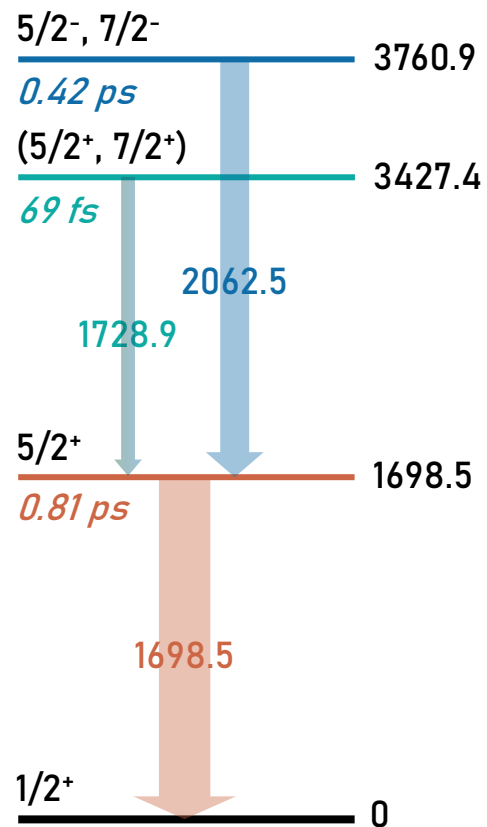
Pre-analysis by F. Drent (GSI)

May 2026: $^{22}\text{Ne} + ^{238}\text{U}$

- Proton contribution to deformation along $N = 14$

^{27}Mg

State: 1698.5 keV

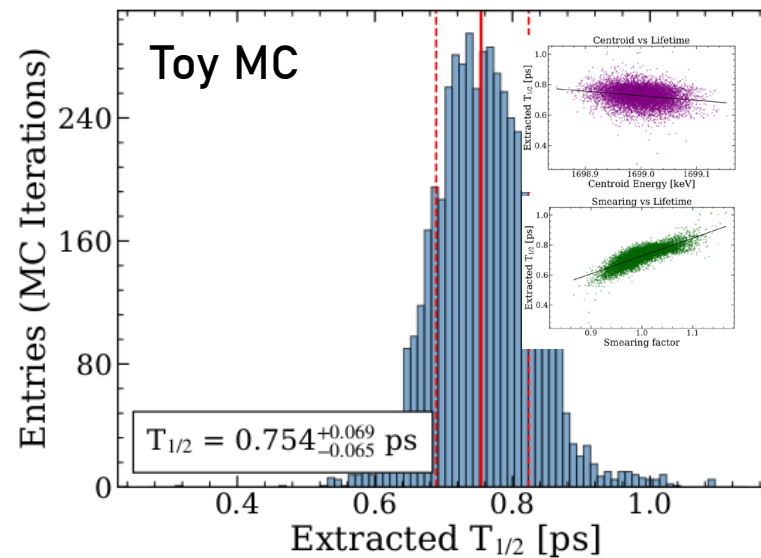
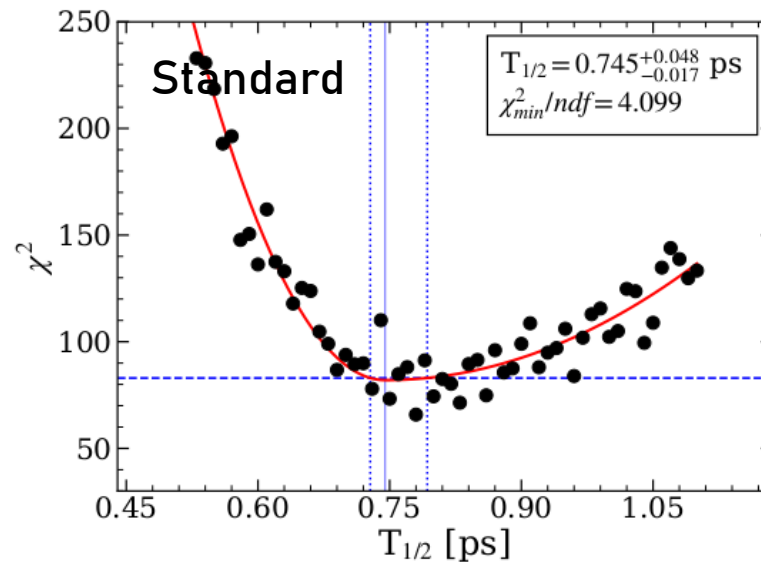
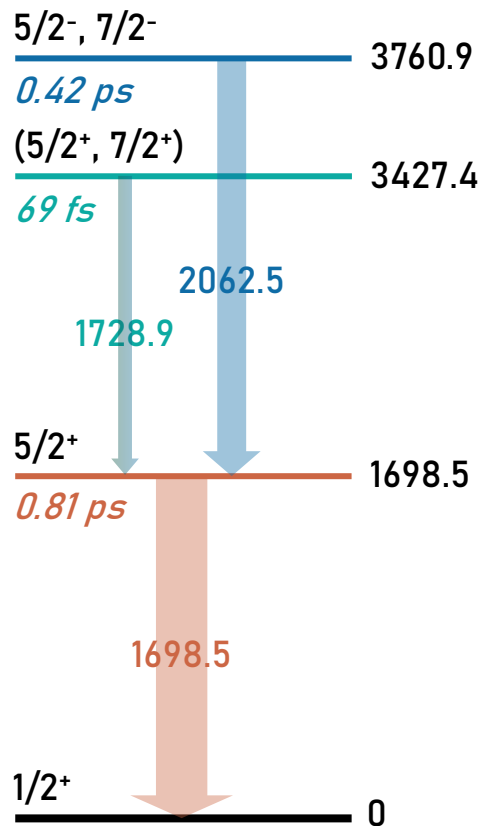


DSAM Benchmarks on $^{27,28}\text{Mg}$

Lifetimes

^{27}Mg

State: 1698.5 keV

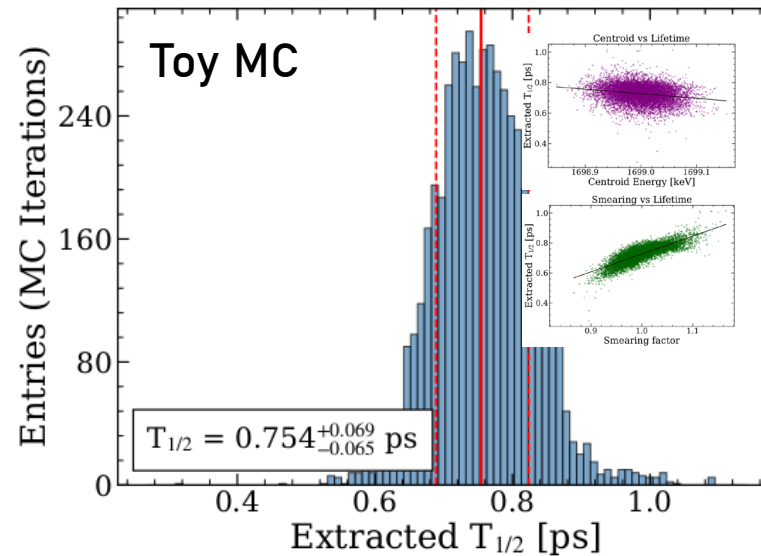
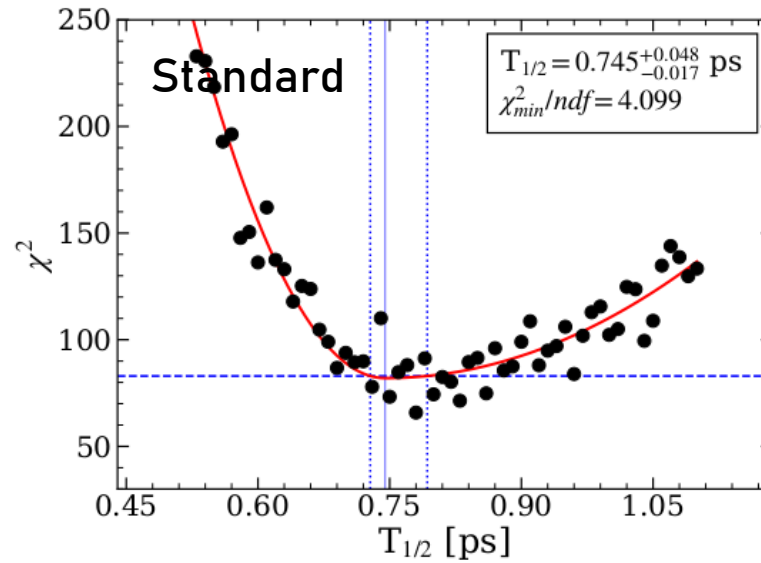
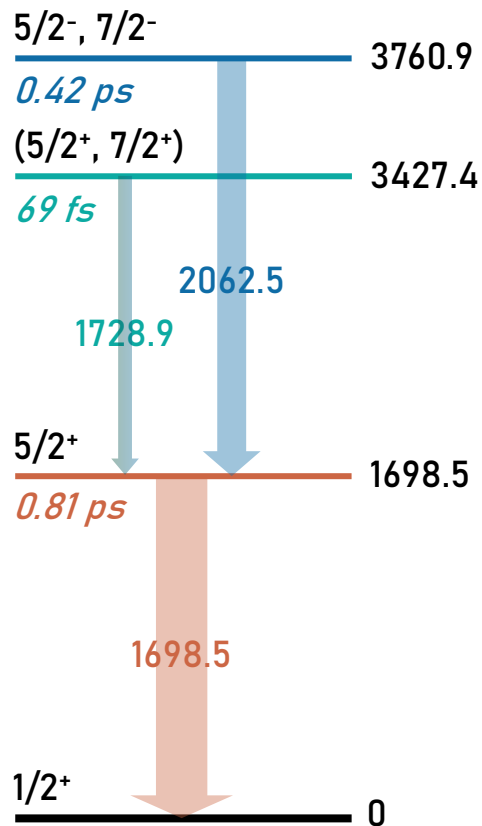


DSAM Benchmarks on ^{27}Mg

Lifetimes

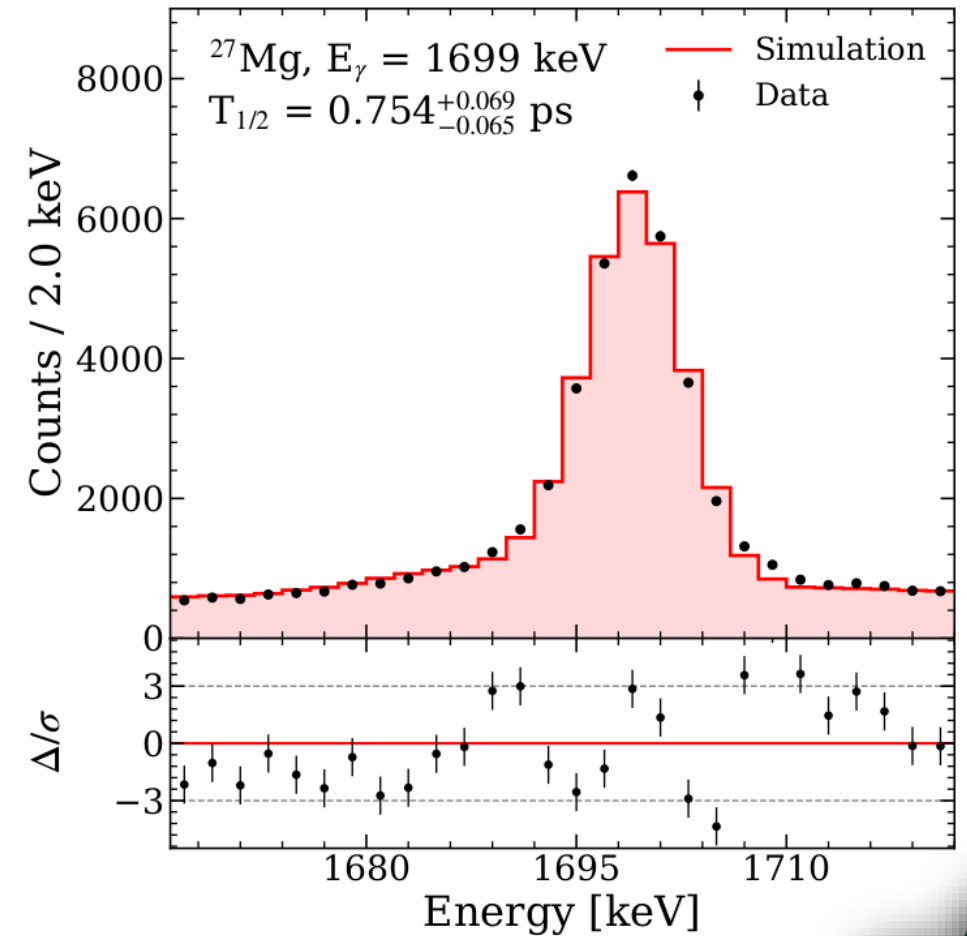
^{27}Mg

State: 1698.5 keV



$$T_{1/2} = 754^{+69}_{-65}\text{ fs}$$

$$\text{NNDC: } T_{1/2} = 810(170)\text{ fs}$$



DSAM Benchmarks on $^{27,28}\text{Mg}$

Lifetimes

^{27}Mg

State: 1698.5

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

0.42 ps

($5/2^+, 7/2^+$)

69 fs

2062.5

1728.9

$5/2^+$

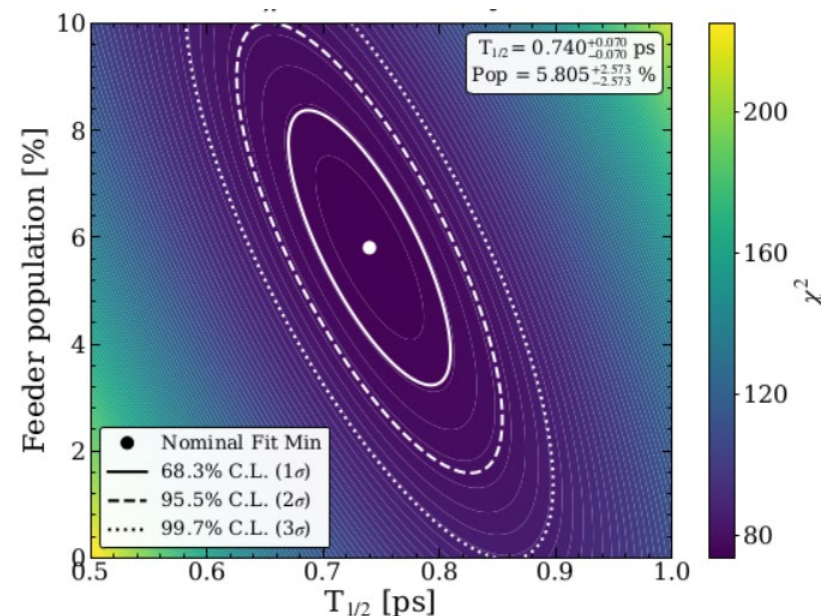
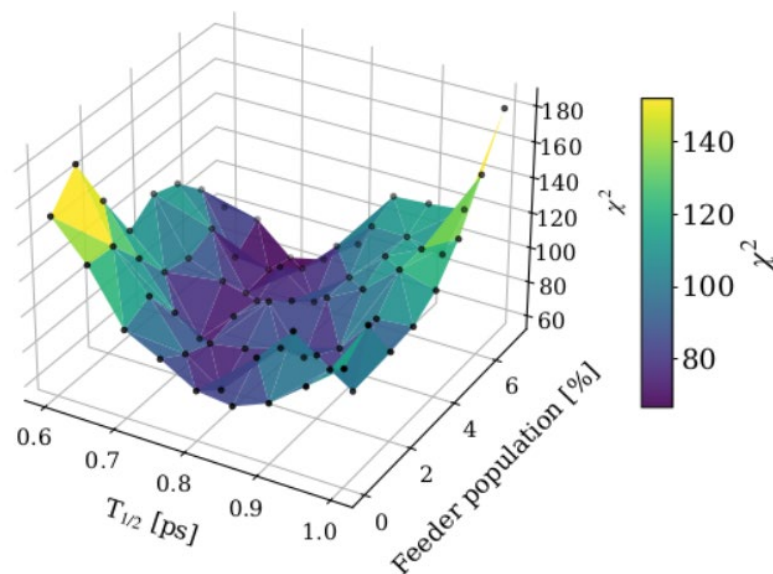
0.81 ps

1698.5

$1/2^+$

Almost same cascade structure as ^{24}Ne !

Optimal 2D Benchmark



$$T_{1/2} = 740^{+70}_{-70} \text{ fs}$$

$$\text{NNDC: } T_{1/2} = 810(170) \text{ fs}$$

$$T_{1/2} = 754^{+69}_{-65} \text{ fs}$$

$$810(170) \text{ fs}$$

Simulation
Data

Extracted $T_{1/2}$ [ps]

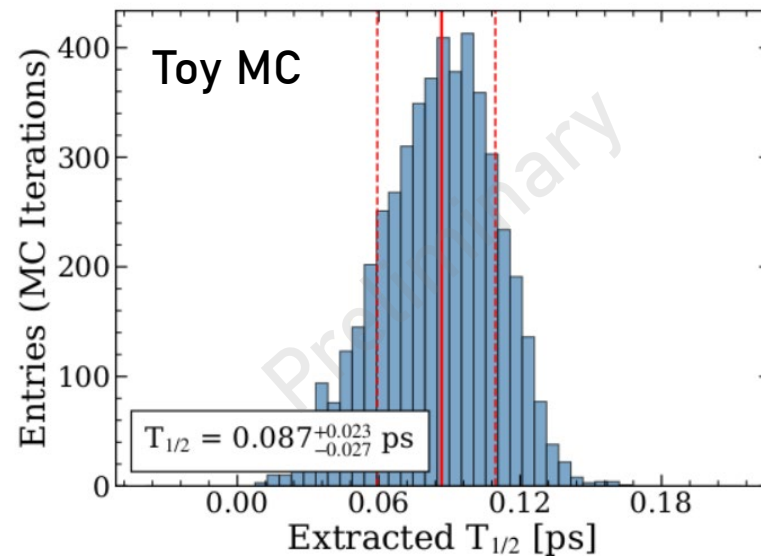
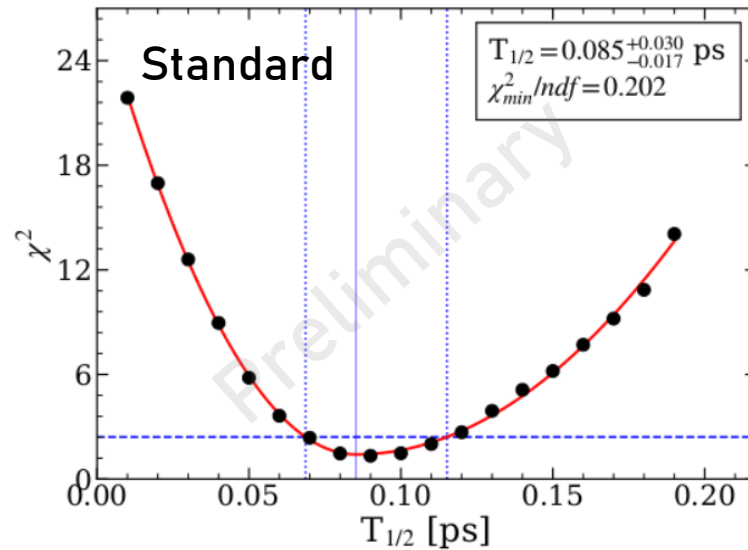
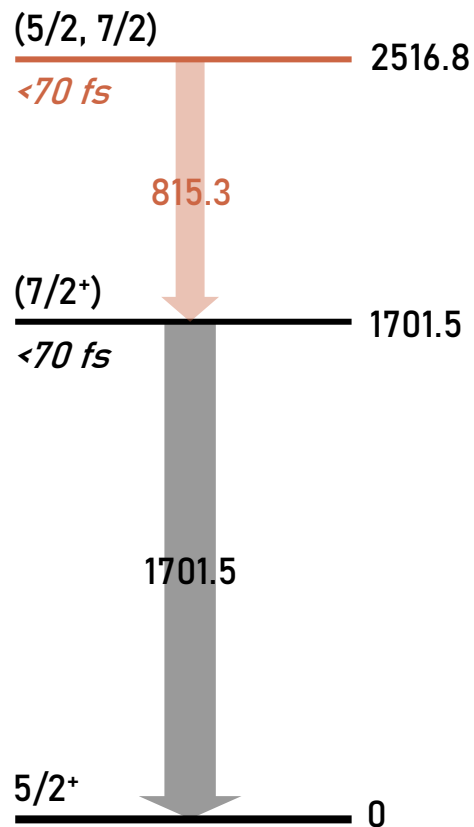
Energy [keV]

New measurements on ^{23}Ne

Lifetimes

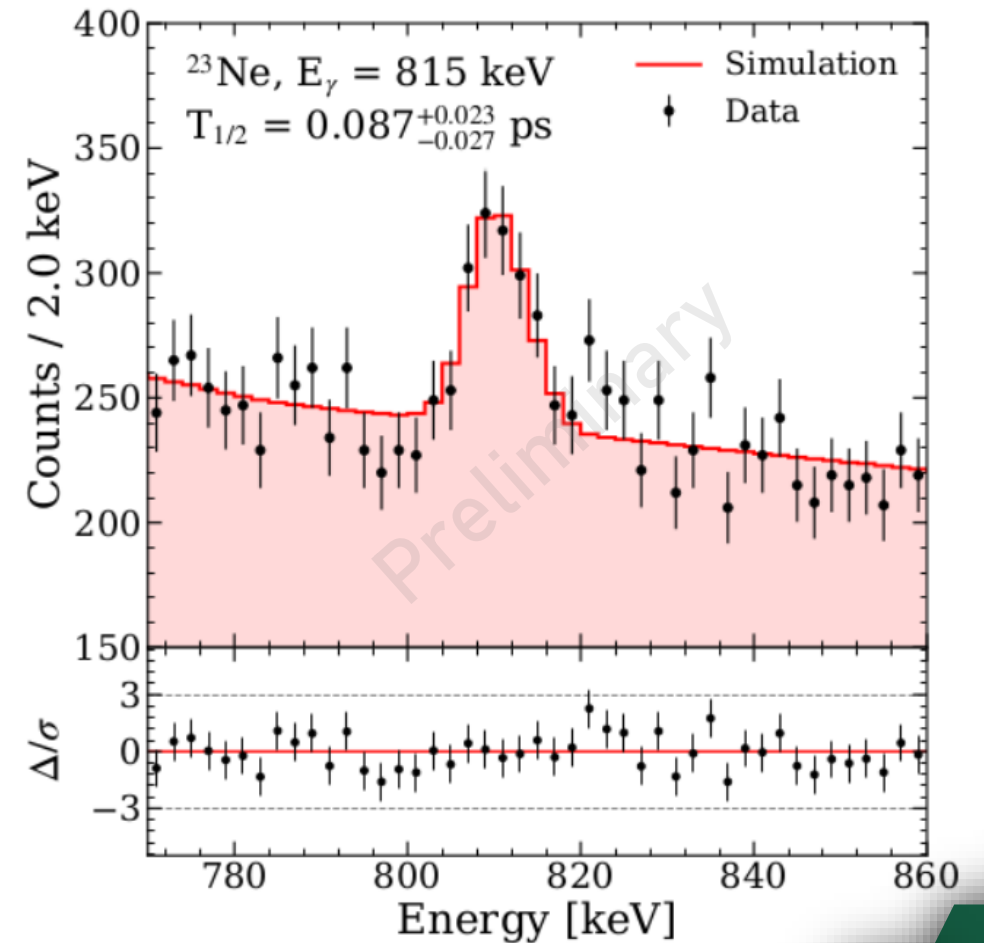
^{23}Ne

State: 2516.8 keV



$$T_{1/2} = 87^{+23}_{-27} \text{ fs}$$

$$\text{NNDC: } T_{1/2} < 70 \text{ fs}$$

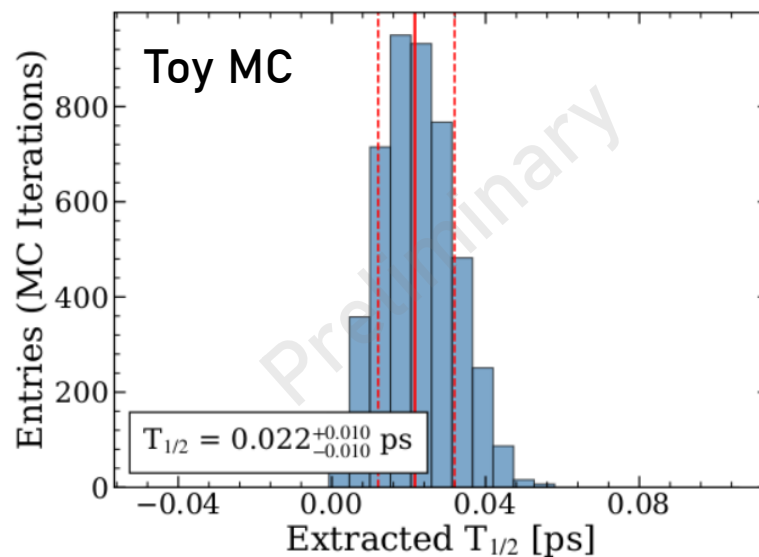
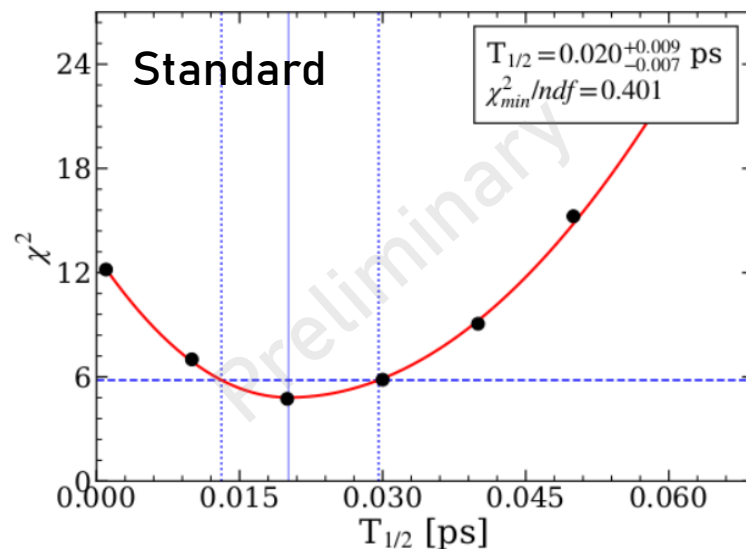
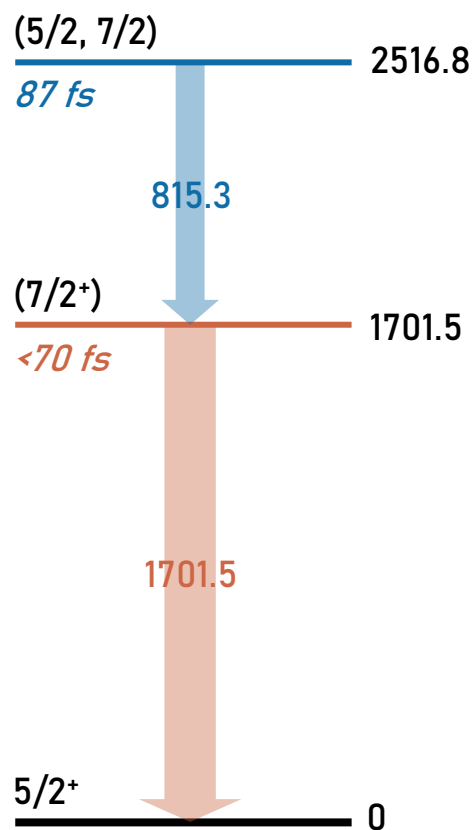


New measurements on ^{23}Ne

Lifetimes

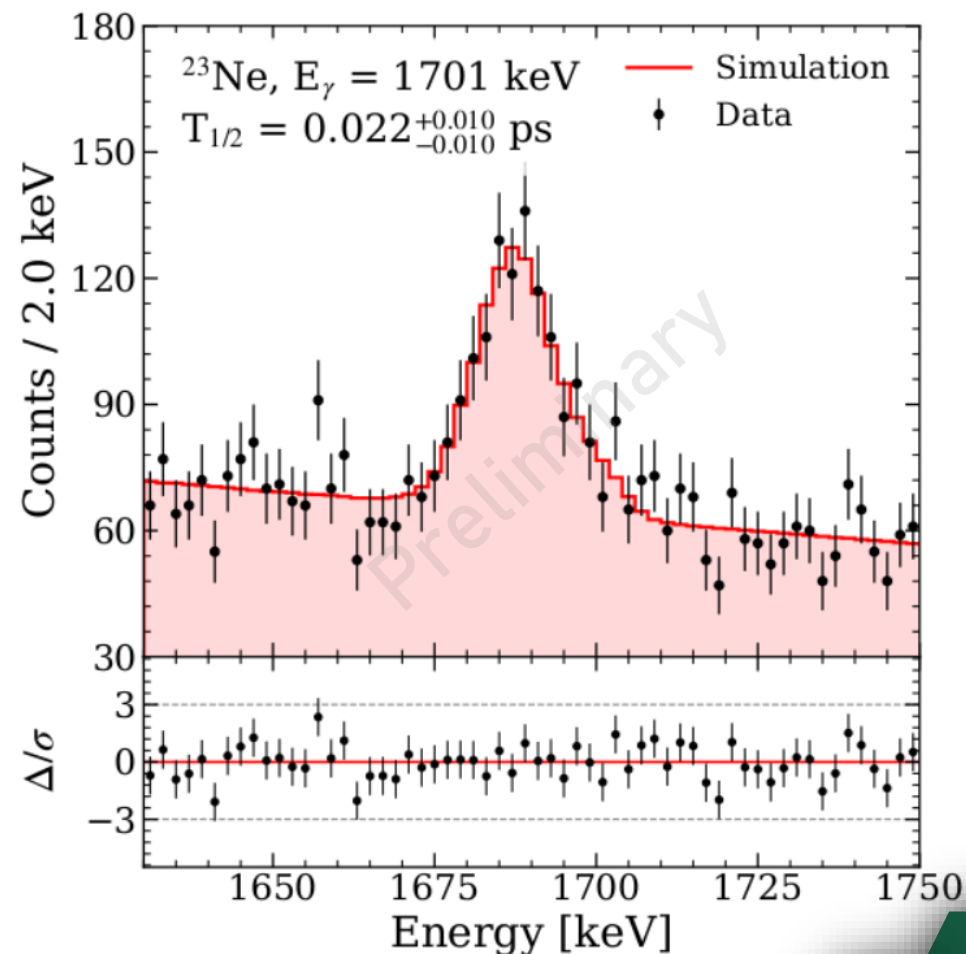
^{23}Ne

State: 1701.5 keV



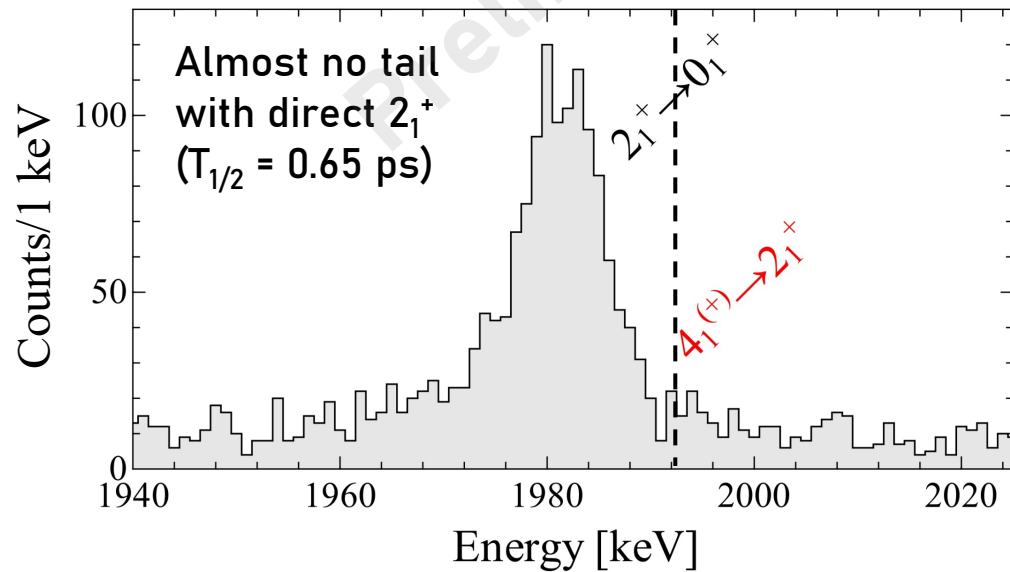
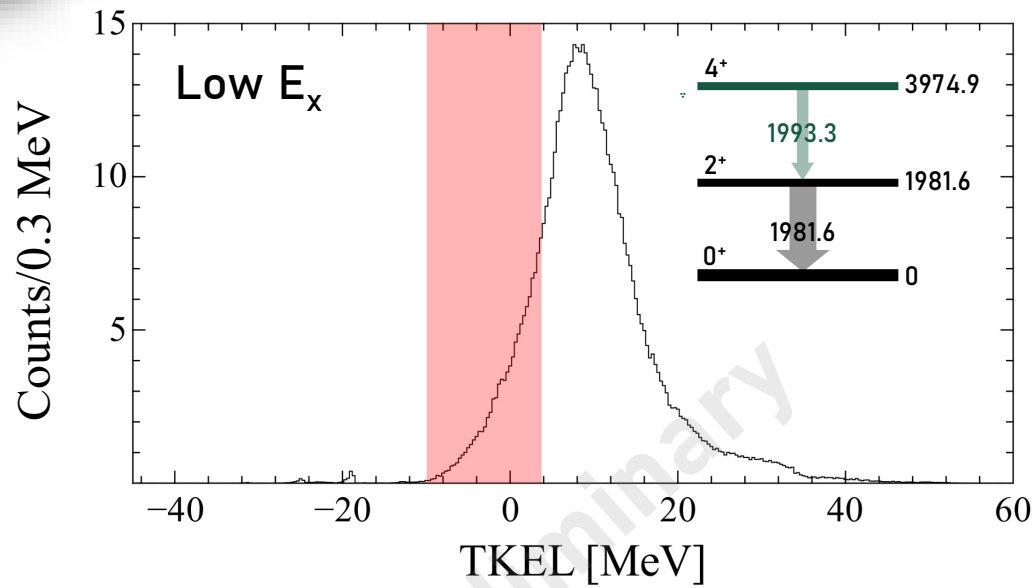
$$T_{1/2} = 22^{+10}_{-10} \text{ fs}$$

$$\text{NNDC: } T_{1/2} < 70 \text{ fs}$$



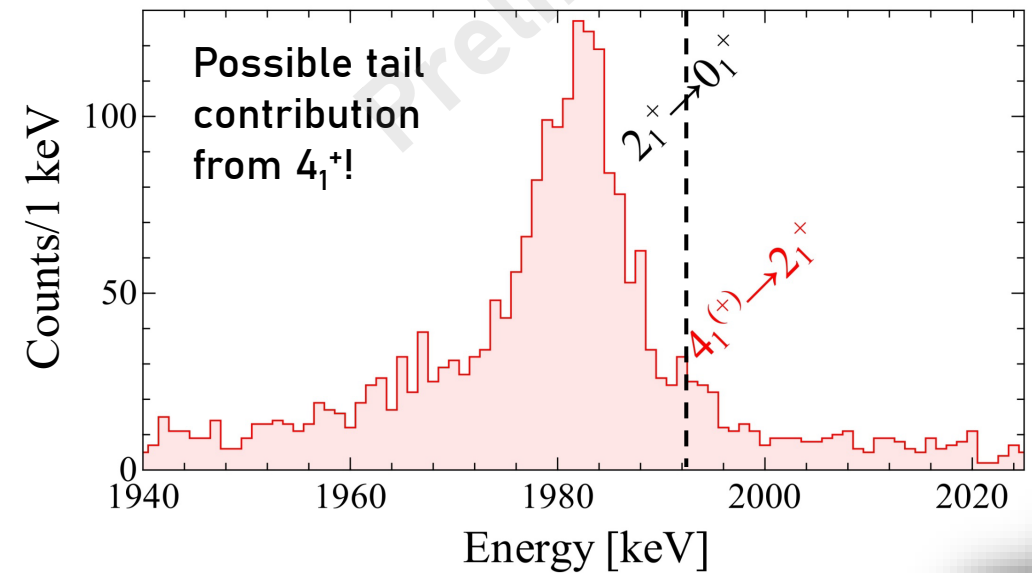
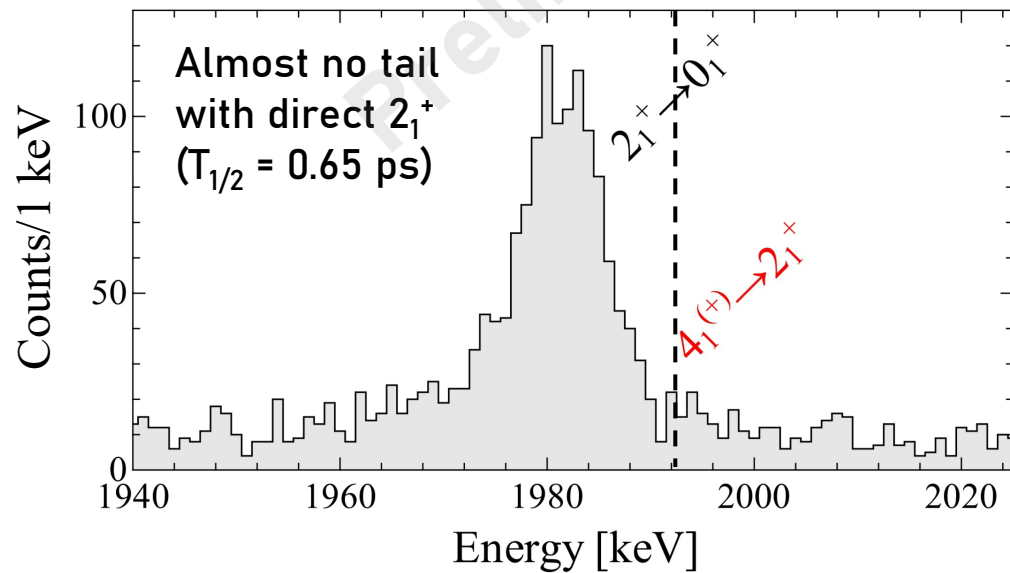
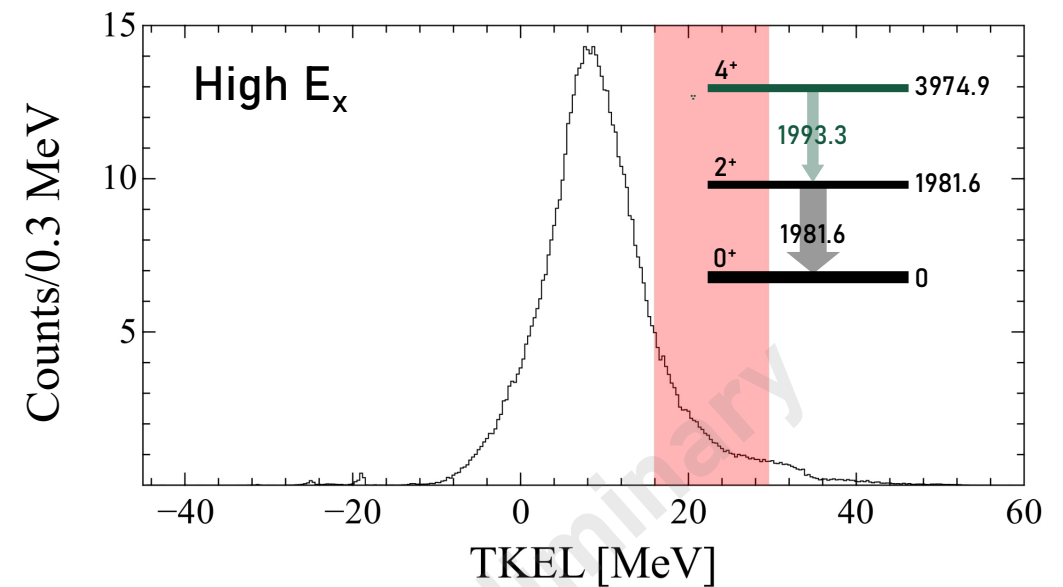
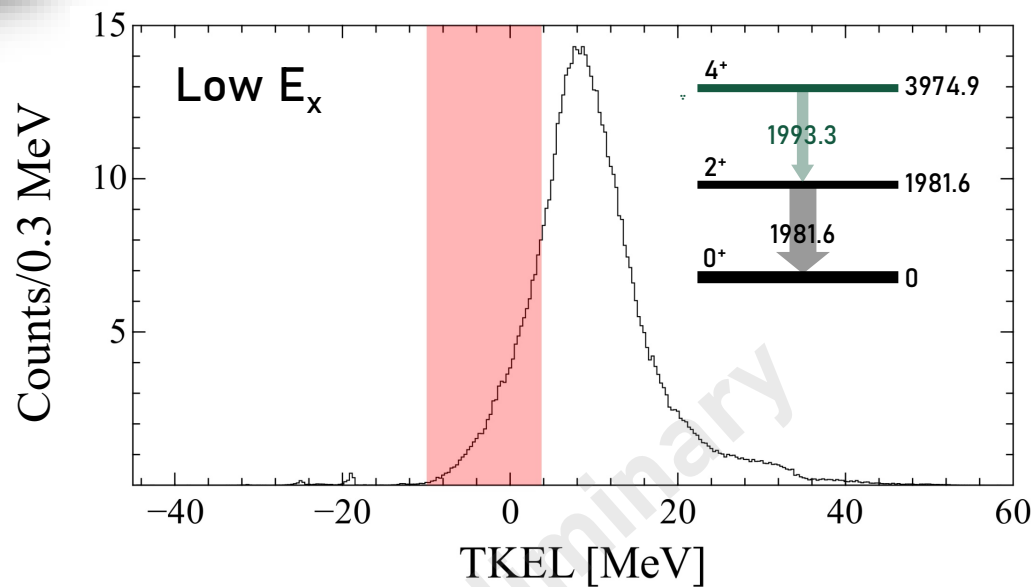
^{24}Ne energy doublet sensitivity

Lifetimes



^{24}Ne energy doublet sensitivity

Lifetimes





- The AGATA-PRISMA campaign targeting Ne and Mg nuclei toward the Island of Inversion is now completed.
- Decay level scheme were extracted for $^{23,24,25}\text{Ne}$, including the low energy doublet in ^{24}Ne .
- Simulation-based DSAM was successfully benchmarked; lifetimes extraction in progress.
- The analysis on ion- γ angular distributions with AGATA is nearing completion.

26th AGATA Week and ACC meeting – September 8th



D. Genna^[1,2], F. Drent^[3], K. Wimmer^[3,4], S. Bottoni^[1,2], P. Aguilera^[5], G. Benzoni^[2],
F. Recchia^[6,7], G. Andreetta^[6,7], F. Angelini^[3], M. Balogh^[8], J. Bardak^[3,9], J. Benito^[10],
B. Bles^[3,9], A. Bracco^[1,2], D. Brugnara^[10], S. Carollo^[6,7], Z. Chen^[3], F. Conca^[1,2], L. Corradi^[10],
G. Corbari^[1,2], F. C. L. Crespi^[1,2], M. del Fabbro^[11], A. Ertoprak^[6,7], E. Fioretto^[10], F. Galtarossa^[6],
A. Giaz^[2], A. Goasduff^[10], B. Gongora Servin^[10], A. Gottardo^[10], Gozzelino^[10], B. Greaves^[10],
A. Jungclaus^[12], T. Kröll^[8], G. Kosir^[13], S. Leoni^[1,2], M. Luciani^[1,2], R. Menegazzo^[7], D. Mengoni^[6,7],
B. Million^[2], G. Montagnoli^[7], R. Nicolás del Álamo^[6,7], J. Pellumaj^[6,7], R. Pérez-Vidal^[14],
S. Pigliapoco^[15], E. Pilotto^[10], W. Poklepa^[3], M. Polettini^[3,16], K. Rezyunkina^[6,7], M. Rocchini^[17],
E. Ronning^[10], M. Sedlak^[8], F. Simioni^[6,7], A. Stefanini^[7], A. Togni^[6,7], J. J. Valiente-Dobón^[14],
J. Vesic^[13], L. Zago^[18], I. Zanon^[19].

[1] Dipartimento di Fisica, Università degli Studi di Milano, Italy

[2] INFN Sezione di Milano, Italy

[3] GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany

[4] University of Cologne, Germany

[5] Comisión Chilena de Energía Nuclear (CCHEN), Chile

[6] Dipartimento di Fisica, Università degli Studi di Padova, Italy

[7] INFN Sezione di Padova, Italy

[8] Institute of Physics of the Slovak Academy of Sciences, Slovakia

[9] University of Novi Sad, Serbia

[10] Istituto Nazionale di Fisica Nucleare LNL, Legnaro, Italy

[11] Ruđer Bošković Institute, Croatia

[12] CSIC Madrid, Spain

[13] Jožef Stefan Institute, Slovenia

[14] IFIC Universitat de València, Spain

[15] Grand Accélérateur National d'Ions Lourds, France

[16] Facility for Antiproton and Ion Research in Europe GmbH (FAIR GmbH), Germany

[17] INFN Sezione di Firenze, Italy

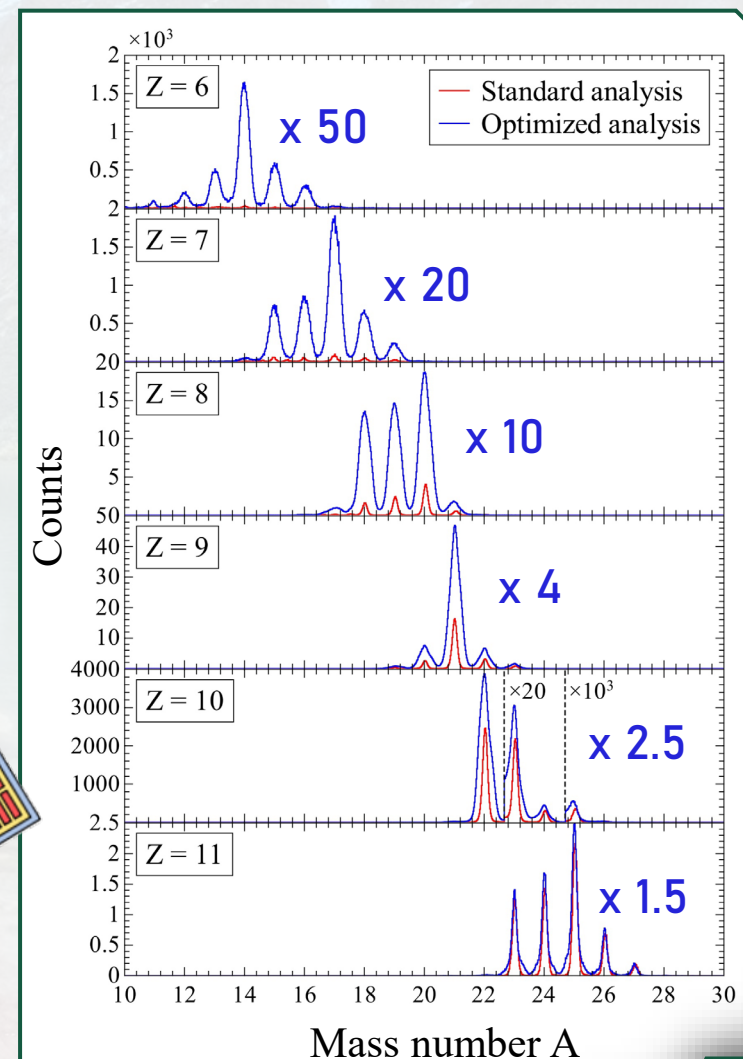
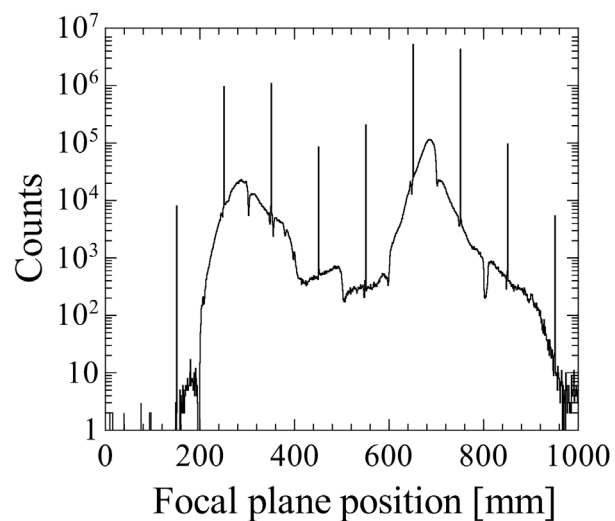
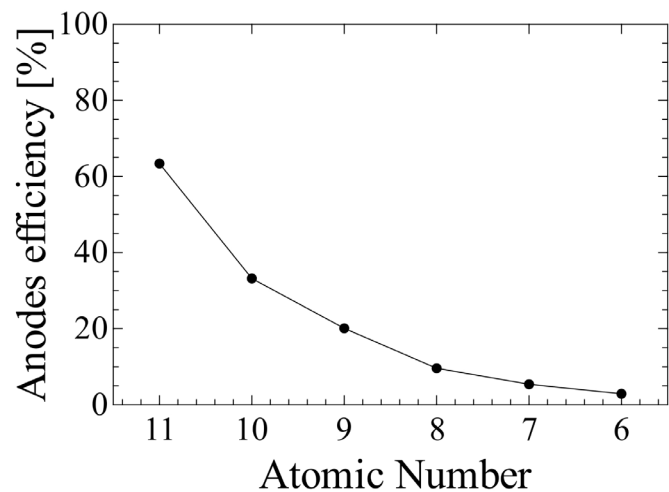
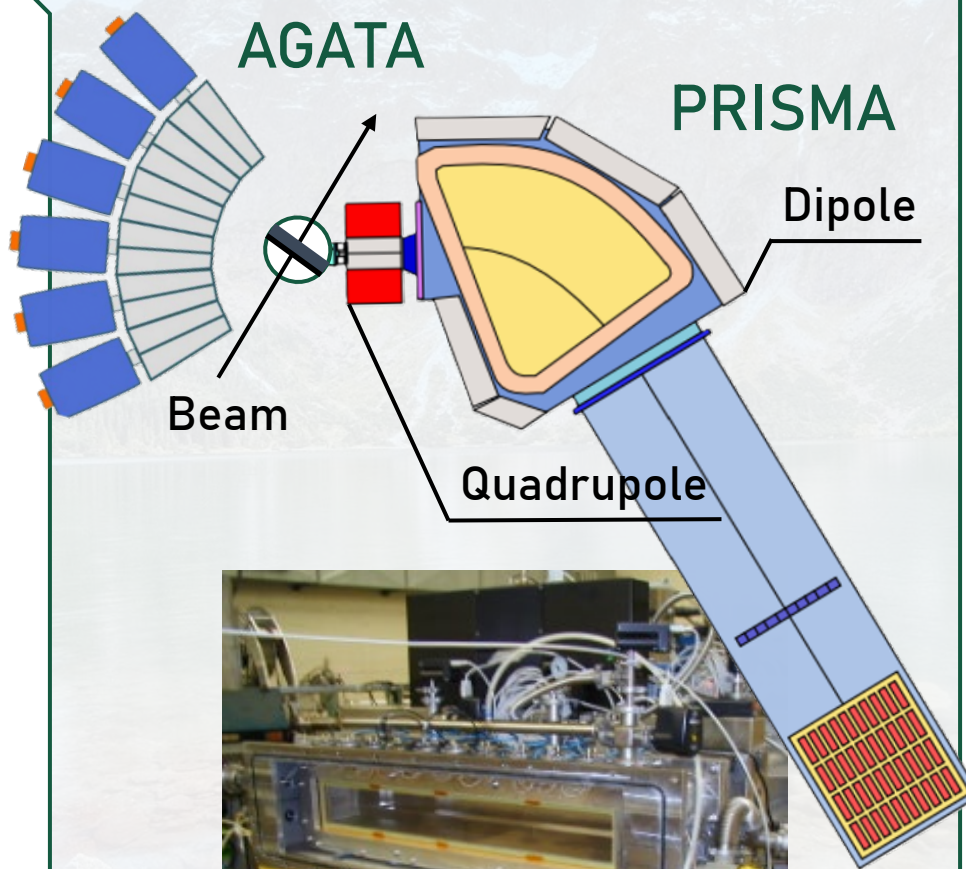
[18] Institut de Physique des Deux Infinis de Lyon, France

[19] KTH Royal Institute of Technology, Sweden

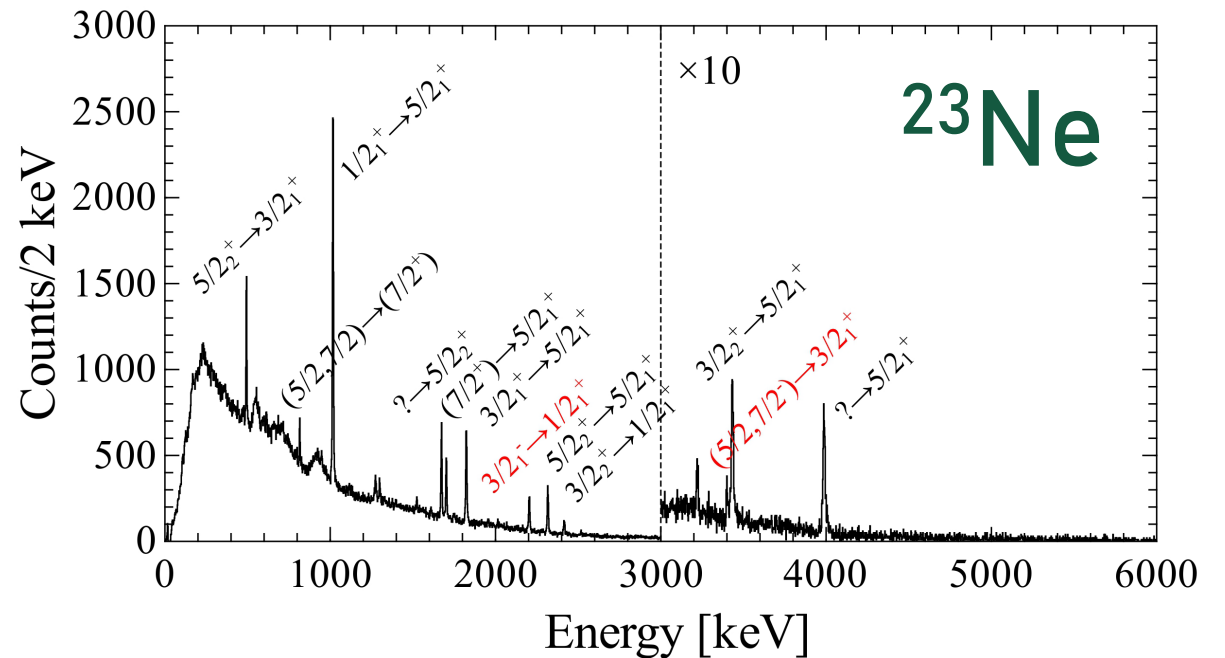
26th AGATA Week and ACC meeting – September 8th

Optimized PRISMA analysis

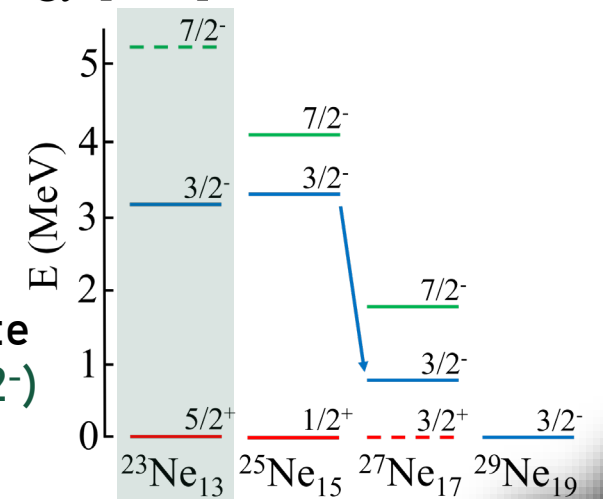
Recovery of only PPAC cathodes events
Suited for light ions



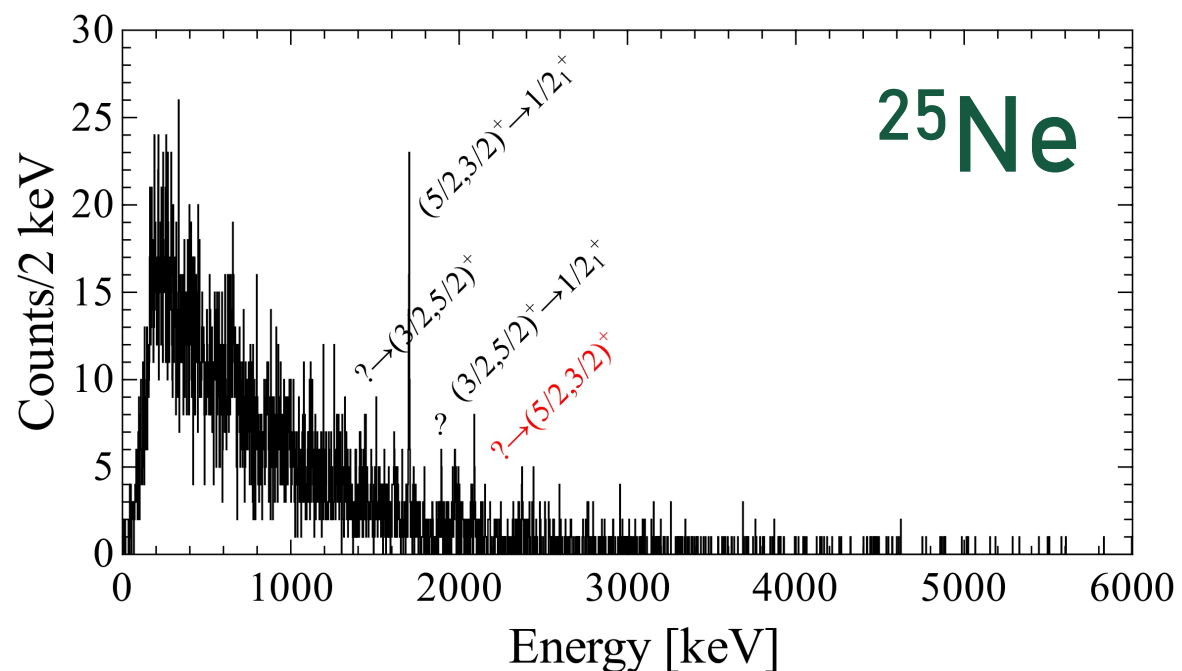
Spectroscopy



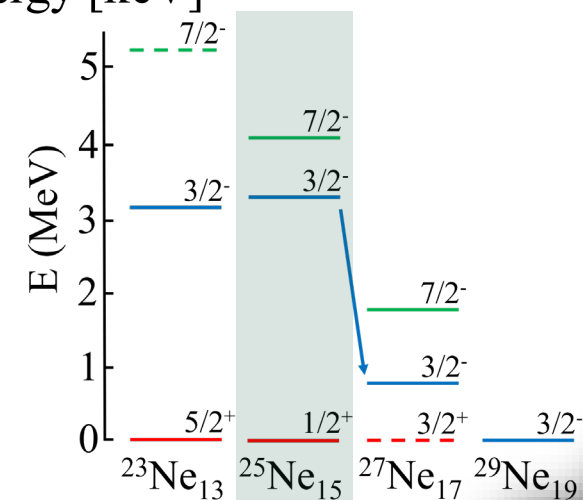
- 3 new levels added
- 7 (+6 uncertain) new observed transitions
- First transition candidate originating from $(5/2, 7/2^-)$ state



Spectroscopy



- Phys. Rev. Lett. 104 192501 2010

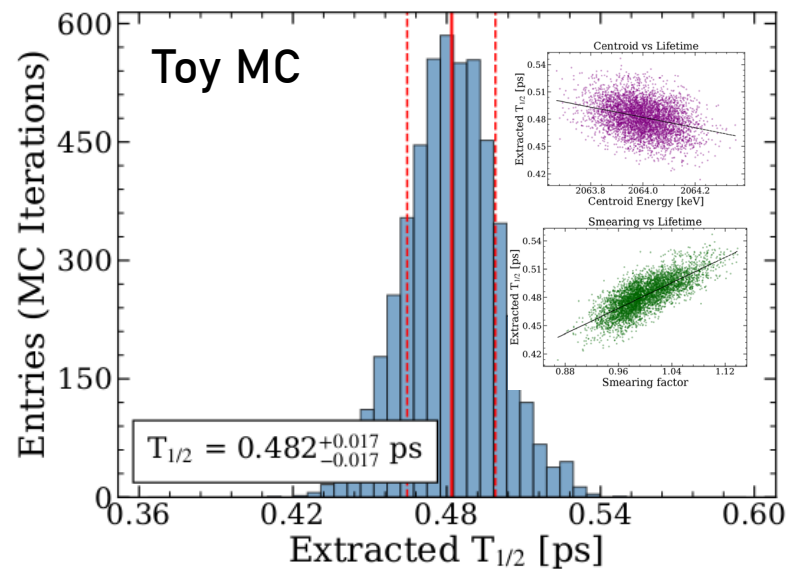
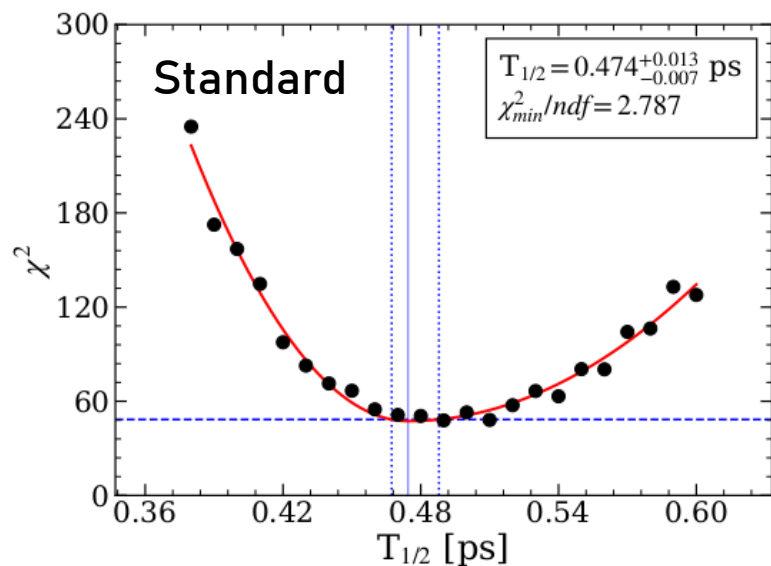
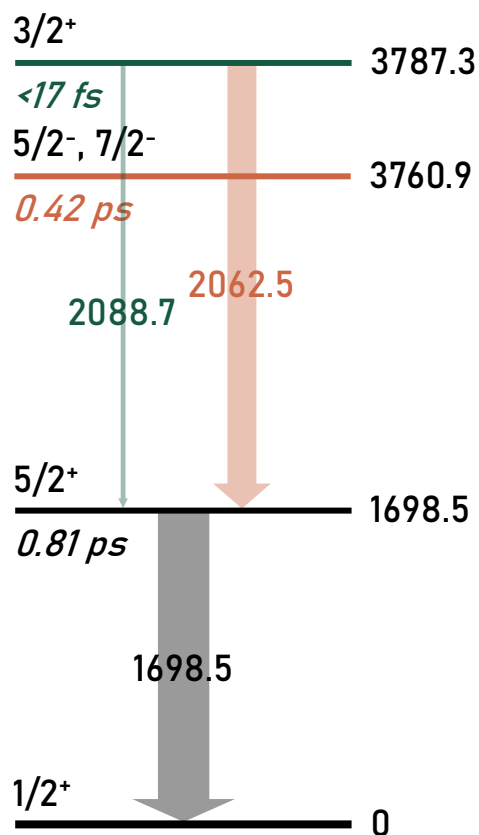


DSAM Benchmarks on ^{27}Mg

Lifetimes

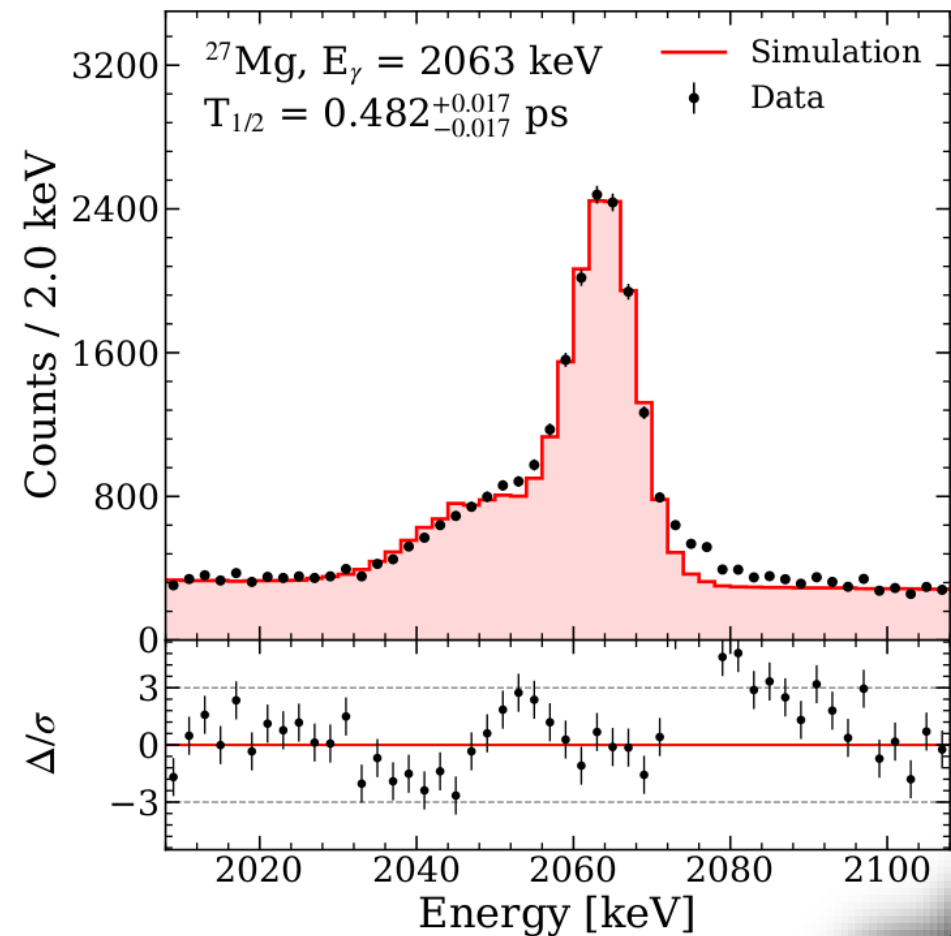
^{27}Mg

State: 3760.9 keV



$$T_{1/2} = 0.482^{+0.017}_{-0.017}\text{ ps}$$

$$\text{NNDC: } T_{1/2} = 0.42(9)\text{ ps}$$

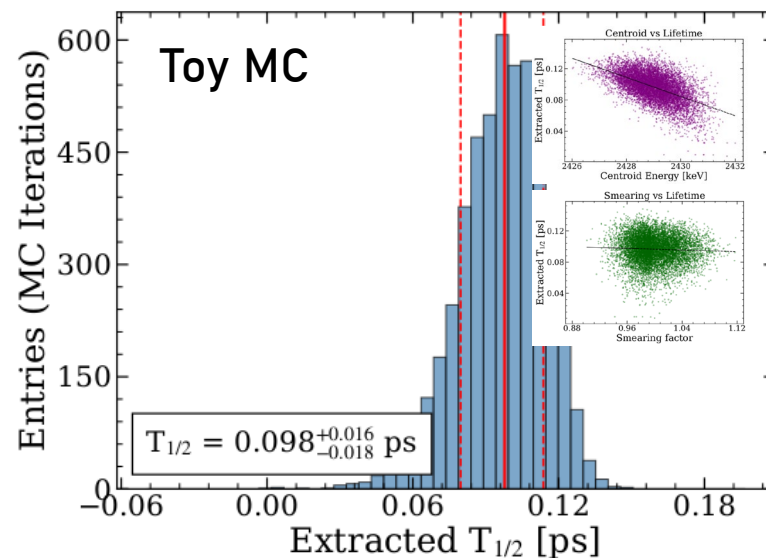
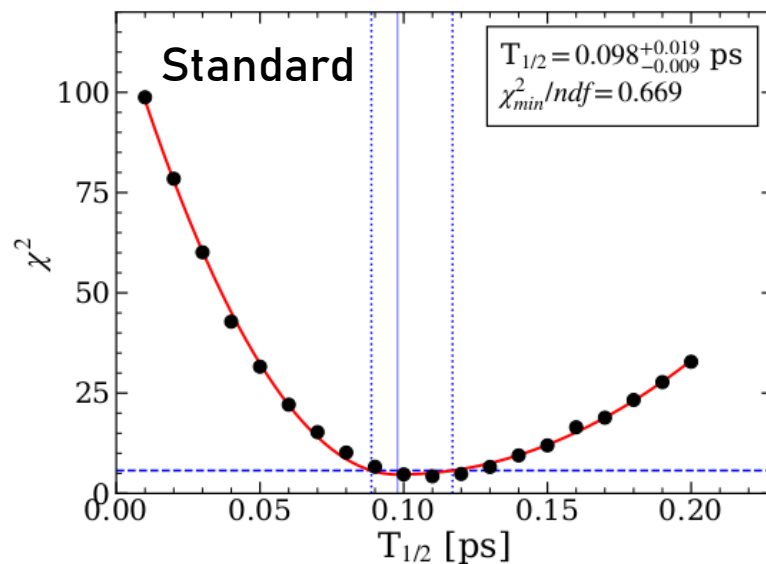
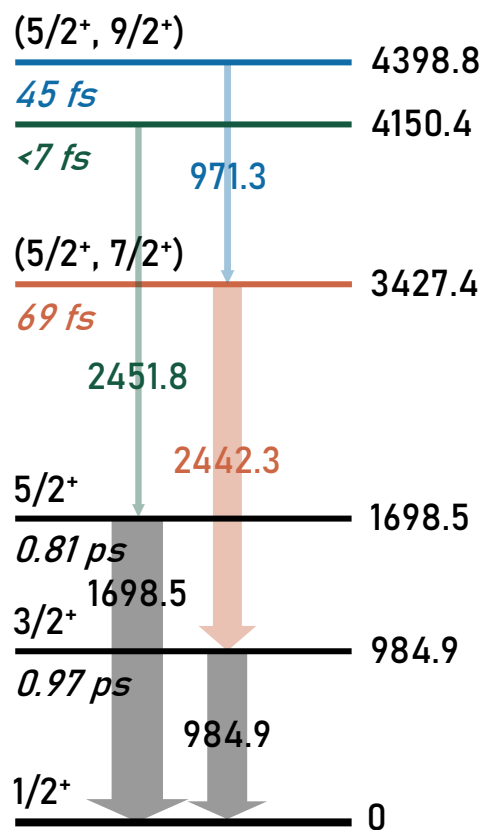


DSAM Benchmarks on ^{27}Mg

Lifetimes

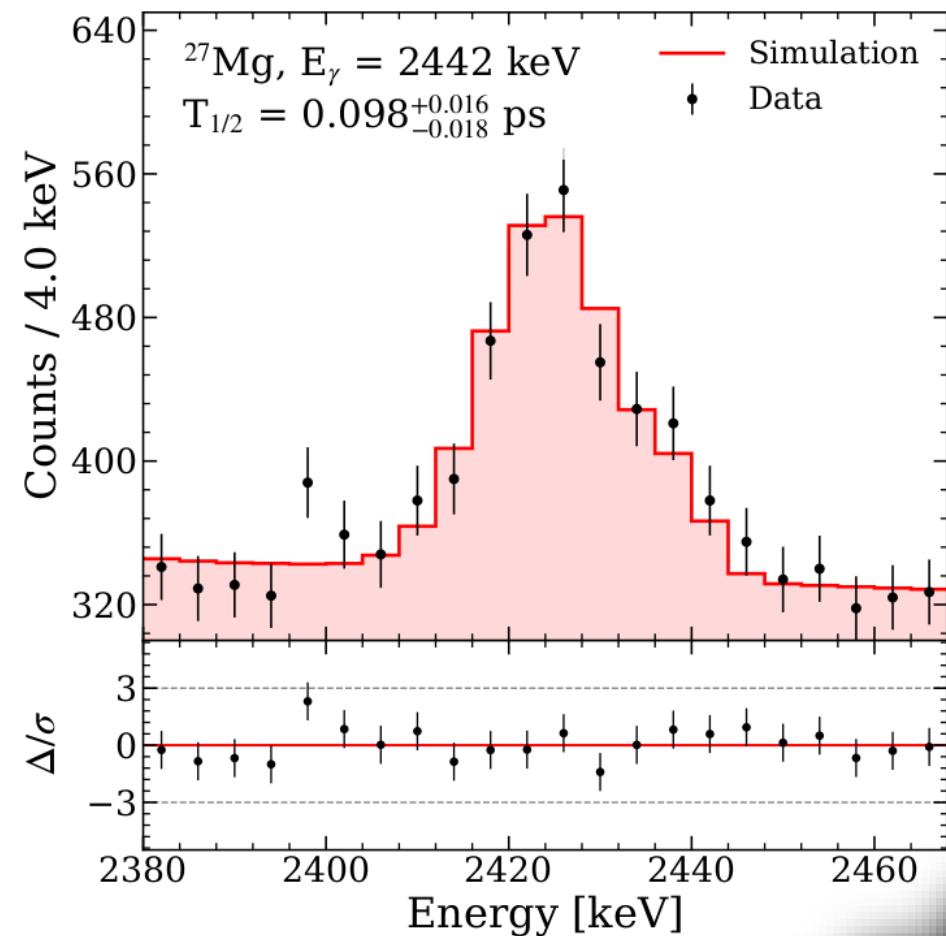
^{27}Mg

State: 3427.4 keV



$$T_{1/2} = 98^{+16}_{-18} \text{ fs}$$

$$\text{NNDC: } T_{1/2} = 69(34) \text{ fs}$$

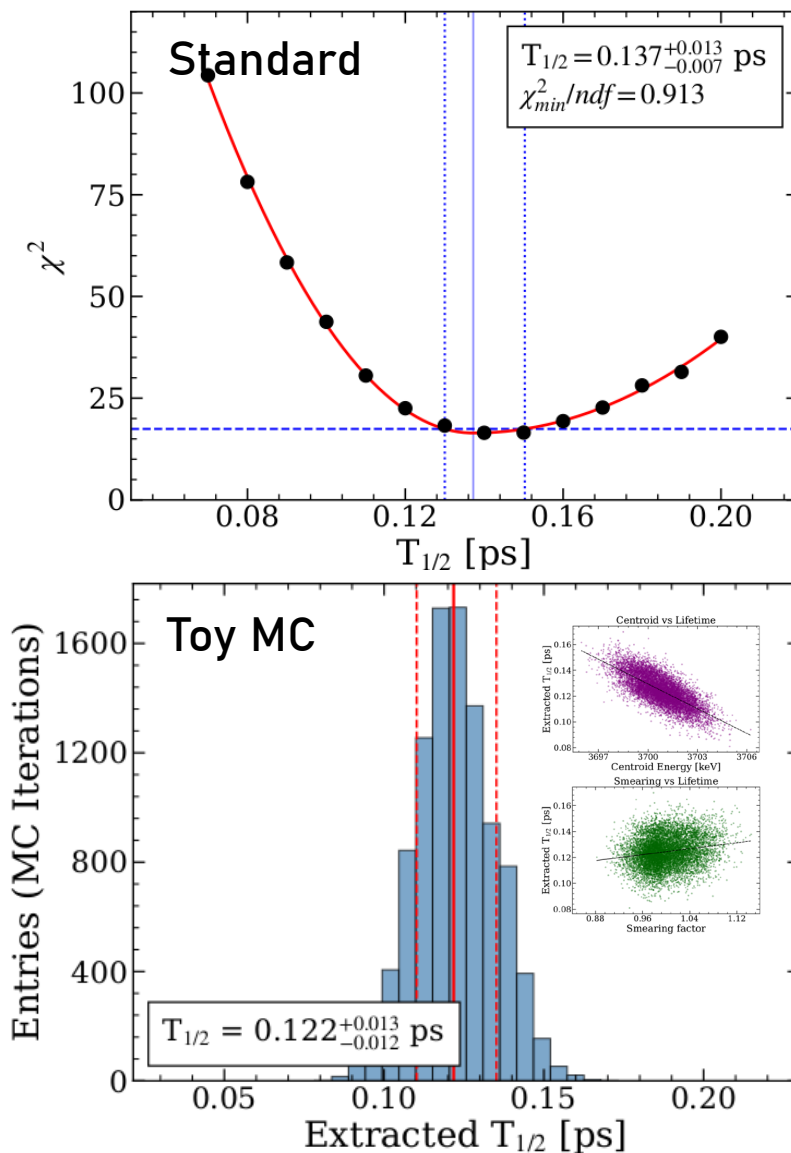
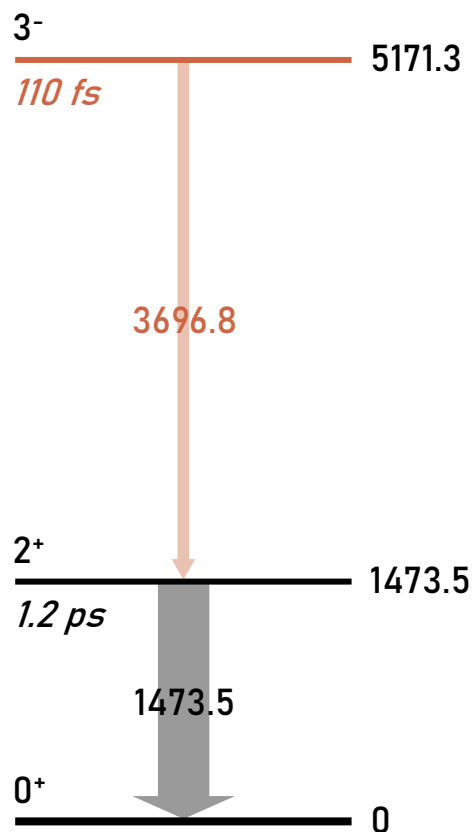


DSAM Benchmarks on $^{27,28}\text{Mg}$

Lifetimes

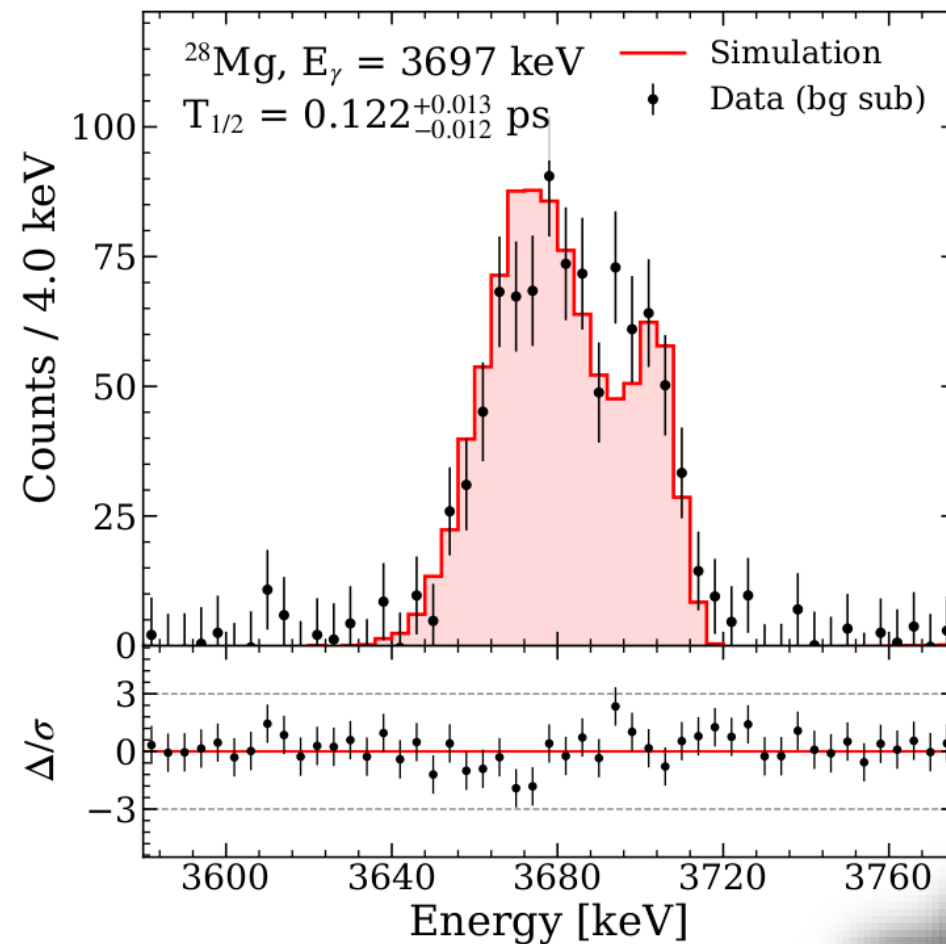
^{28}Mg

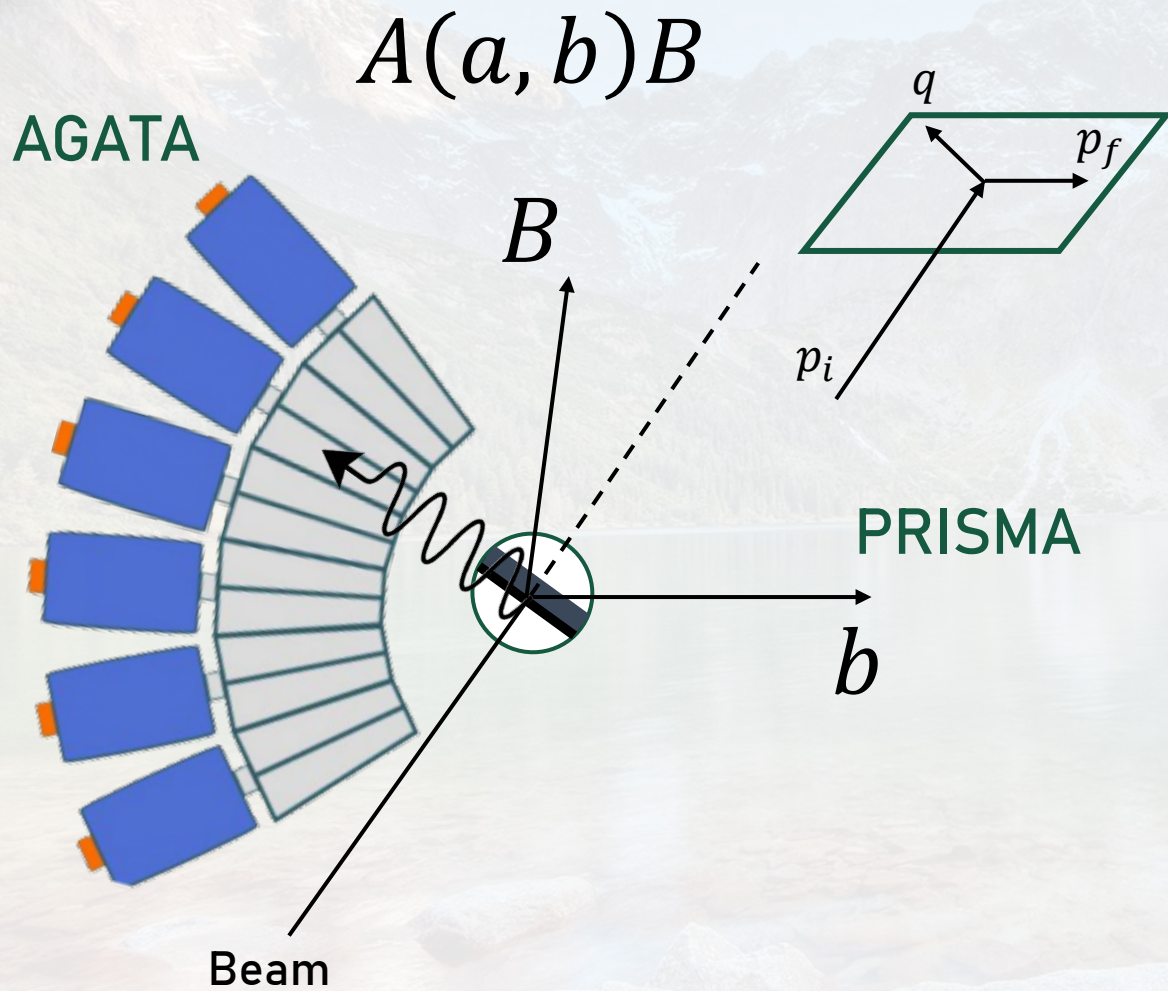
State: 5171.3 keV



$$T_{1/2} = 121^{+13}_{-13} \text{ fs}$$

$$\text{NNDC: } T_{1/2} = 110 (90) \text{ fs}$$



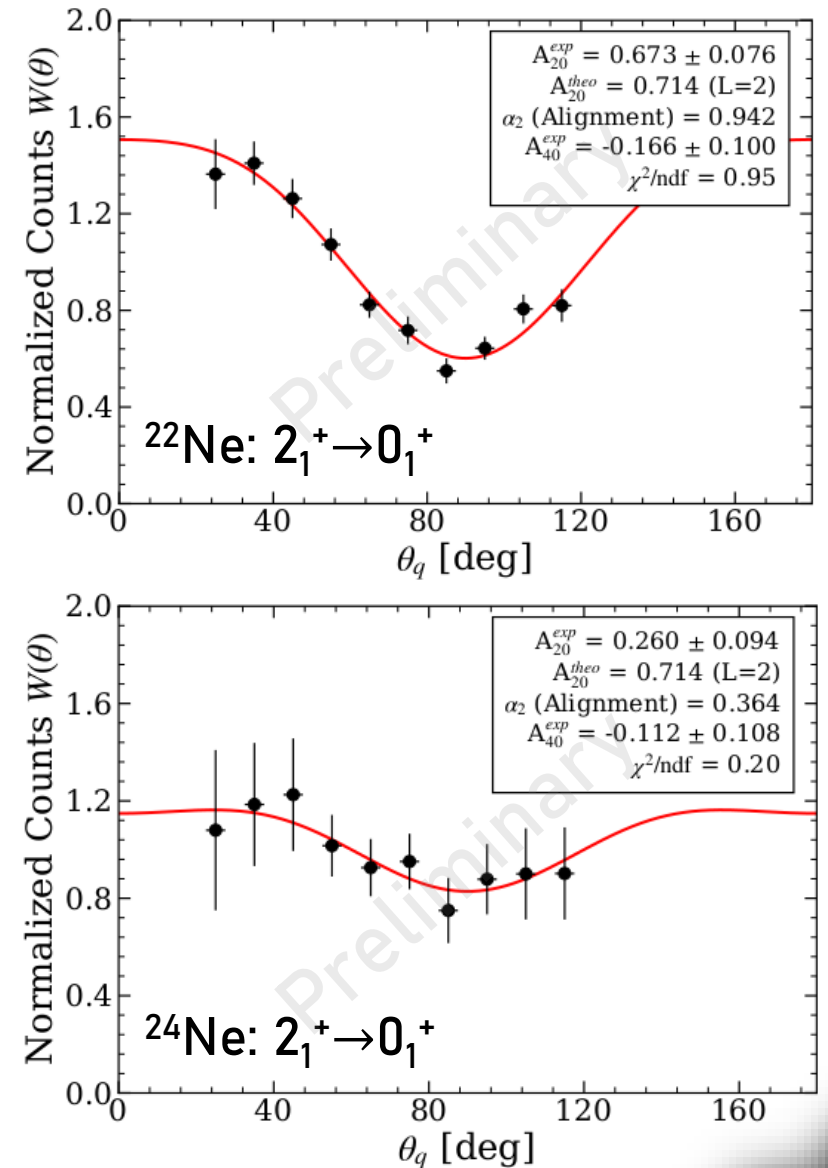


Observed states are prepared once the emitter beam-like fragment is detected in PRISMA

φ selection

Quantization axis	Cylindrical symmetry
Beam	✗
Beam-like (b)	✗
Recoil-like (B)	✓
Normal to reaction plane	✗ (but...)

Reaction plane reconstructed event-by-event



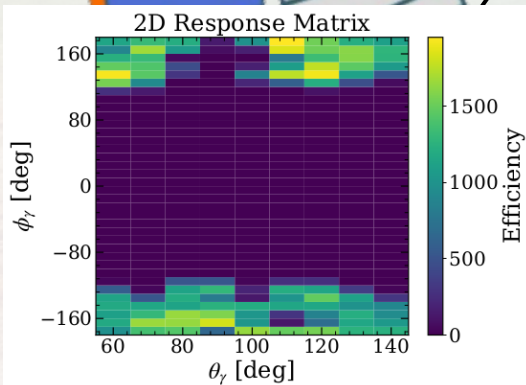
AGATA

$A(a, b)B$

B

PRISMA

b



Cylindrical symmetry
 Sub-states population around $m = \pm 2$
 Need complete $W(\theta, \varphi)$ with mixed parameters: A_{22}, ϕ_{22}
 More statistics is needed when adding mixed parameters...

