Spectroscopy and lifetime measurements toward the Island of Inversion with the AGATA-PRISMA setup

24th AGATA Week – ACC Meeting, Milano, 13/09/2024

Speaker: Davide Genna

Università degli Studi di Milano and INFN

The Collaboration

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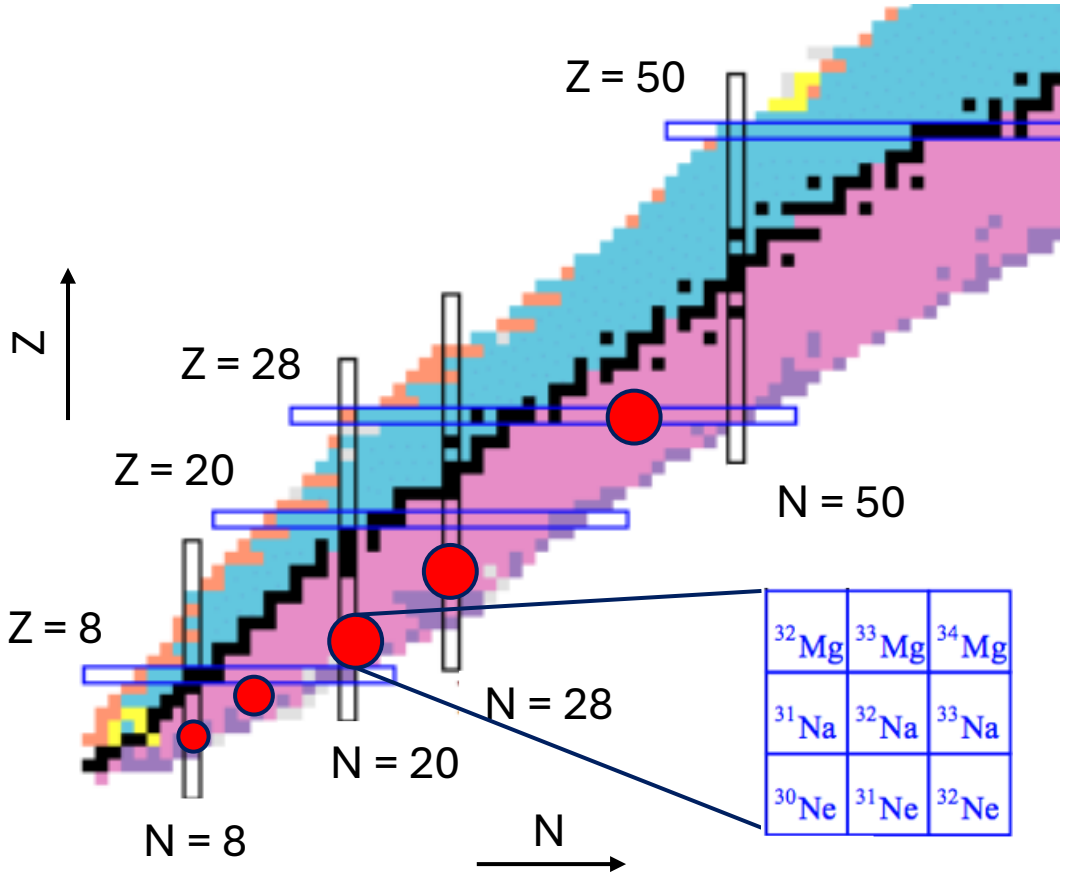
[12] Università degli Studi di Firenze e INFN Sezione di Firenze, Italy
[13] ULB, Brussel, Belgium
[14] Stockholm University, Stockholm, Sweden

Physics case: Island of Inversion at N = 20



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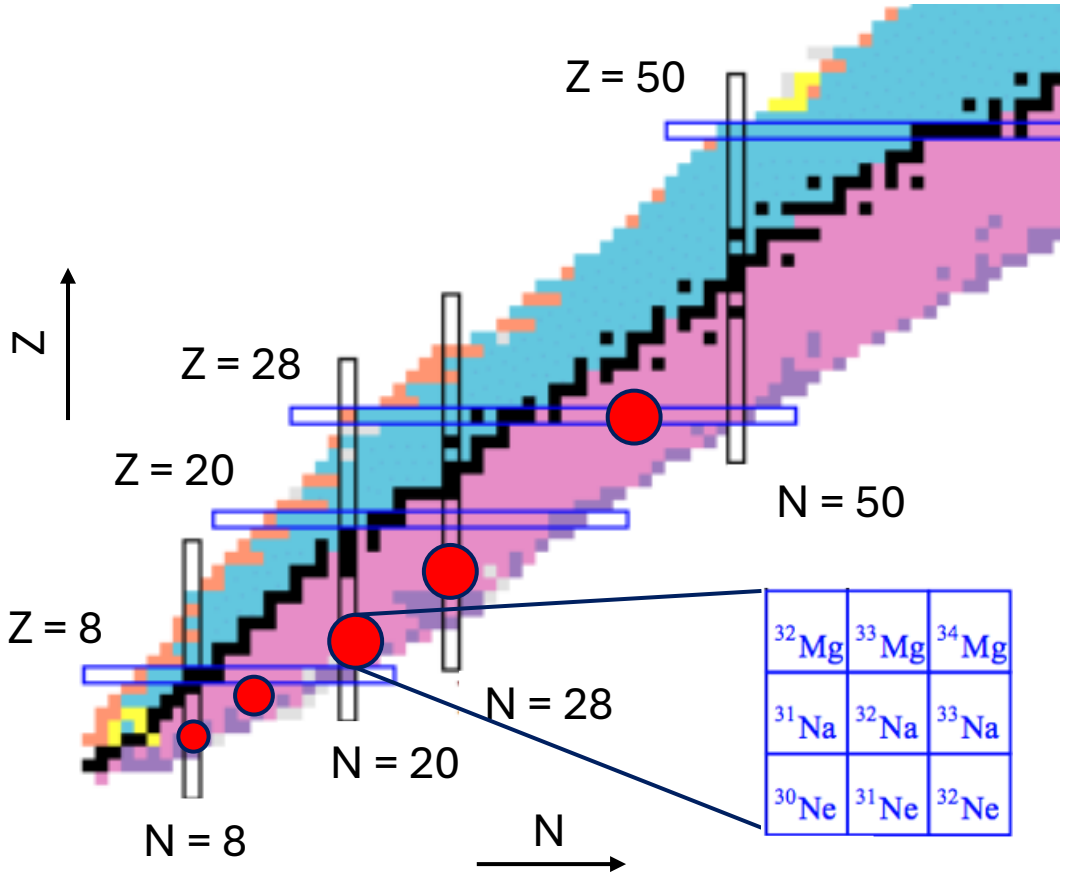

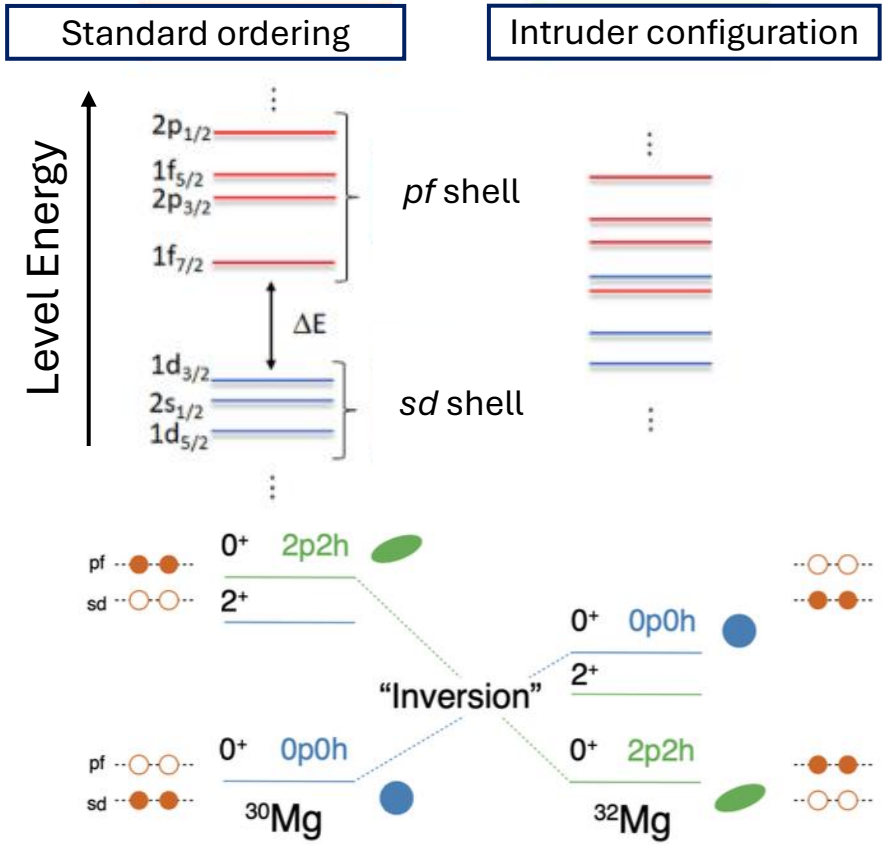

K. Wimmer et al., Phys. Rev. Lett. 105, 252501, 2010.

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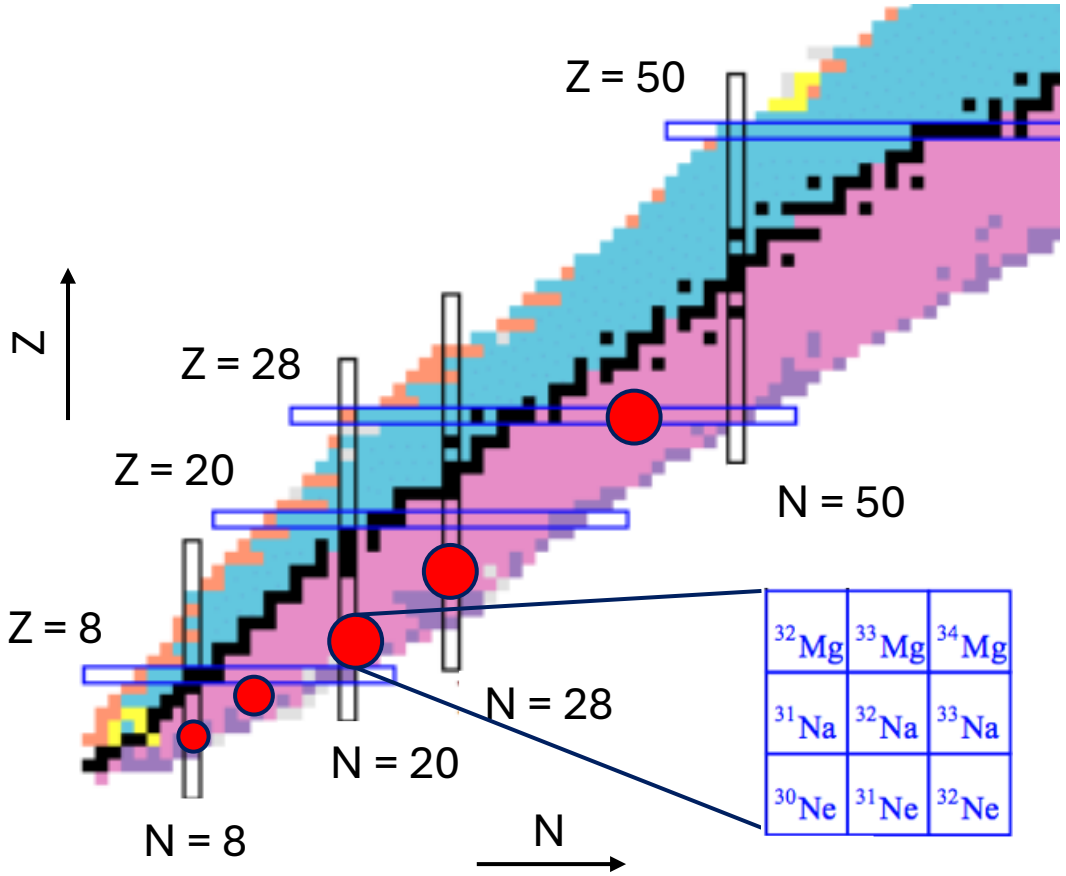
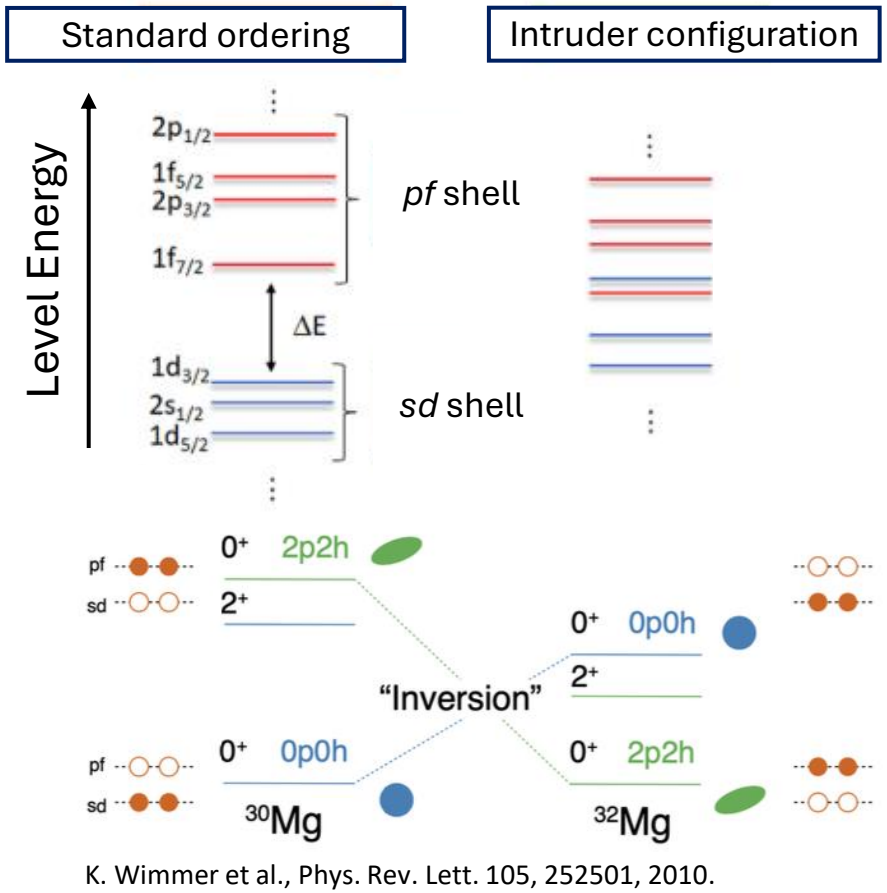


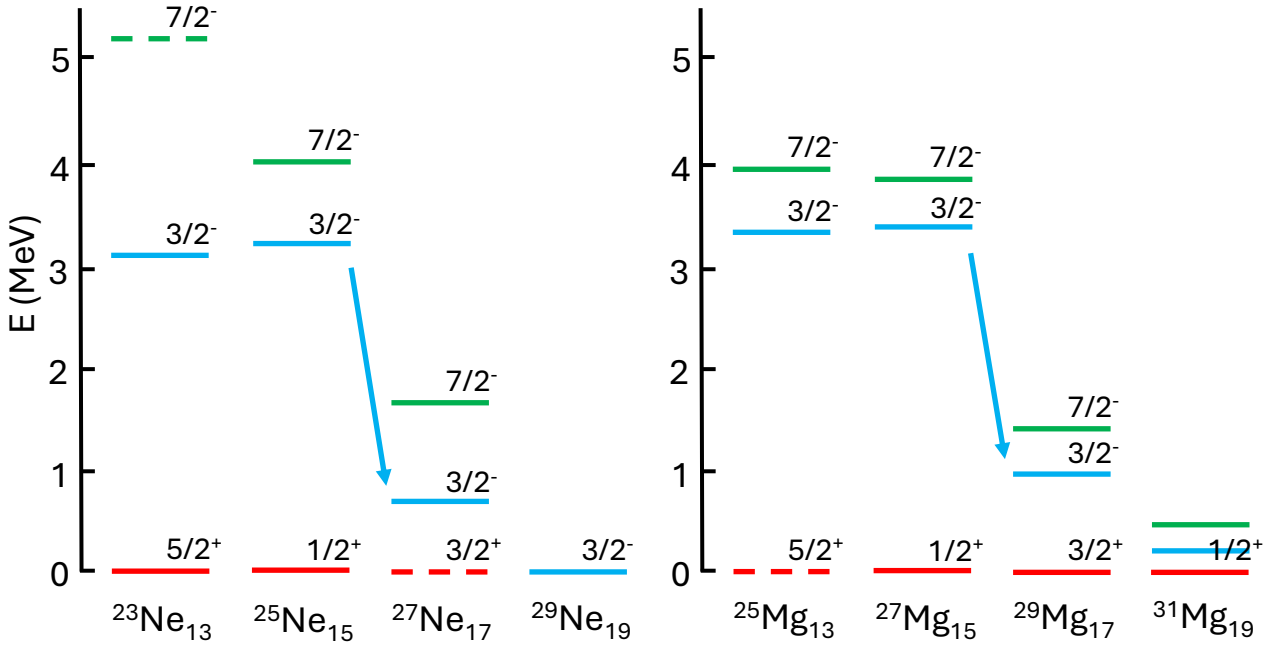


K. Wimmer et al., Phys. Rev. Lett. 105, 252501, 2010.

Main goal: understanding microscopic origin of shell and shape evolution and improve our knowledge on the nature of the nuclear force

Physics case: Island of Inversion at N = 20

Evolution of negative parity states



[23-29]**Ne**: A.E. Champagne et al., Phys. Rev. C, 42, 6, 1990; W.N. Catford et al., Phys. Rev. Letters, 104, 192501, 2010; S.M. Brown et al., Phys. Rev. C, 85, 011302, 2012; N. Kobayashi et al., Phys. Rev. C, 93, 014613, 2016.

[25-31]**Mg**: D.M. Headly et al., Phys. Rev. C 38, 1698, 1988; W. Brendler et al., Z Physik A 281, 75–88, 1977; J. R. Terry et al., Phys. Rev. C 77, 014316, 2008; H. Nishibata et al., Phys. Rev. C 99, 024322, 2019.

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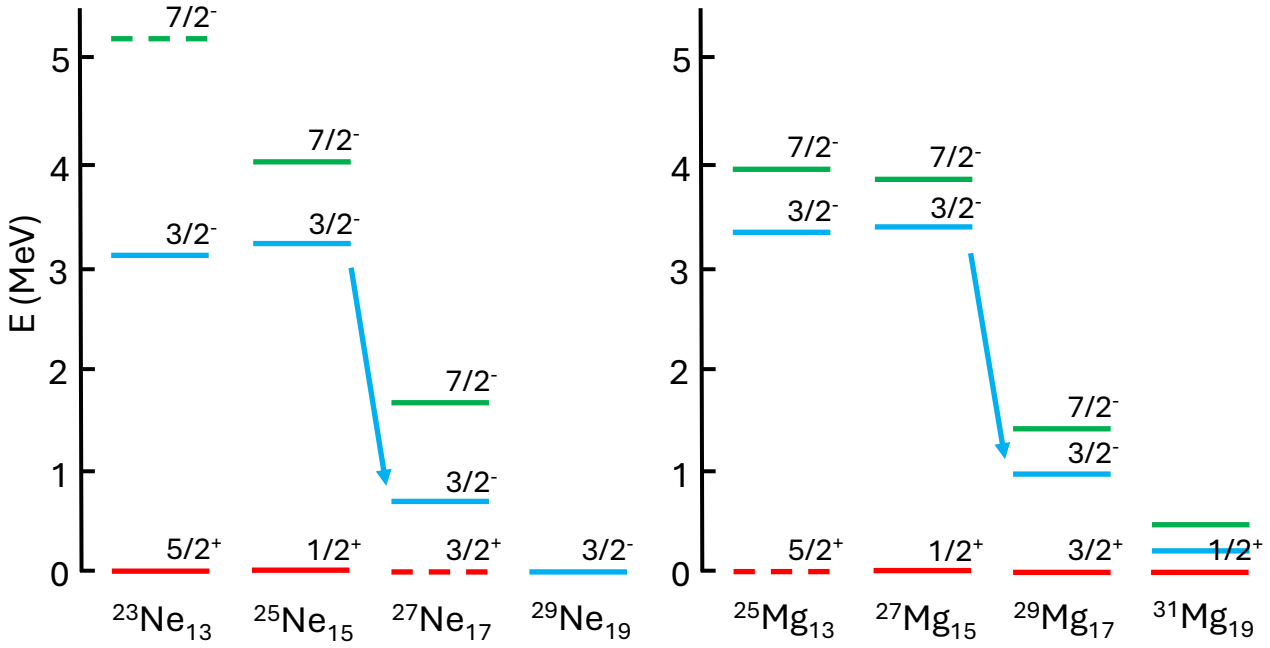

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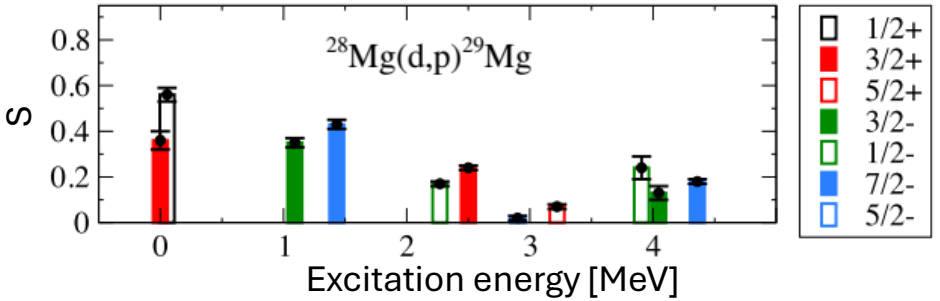

P. T. MacGregor et al., Phys. Rev. C 104, L051301, 2021.

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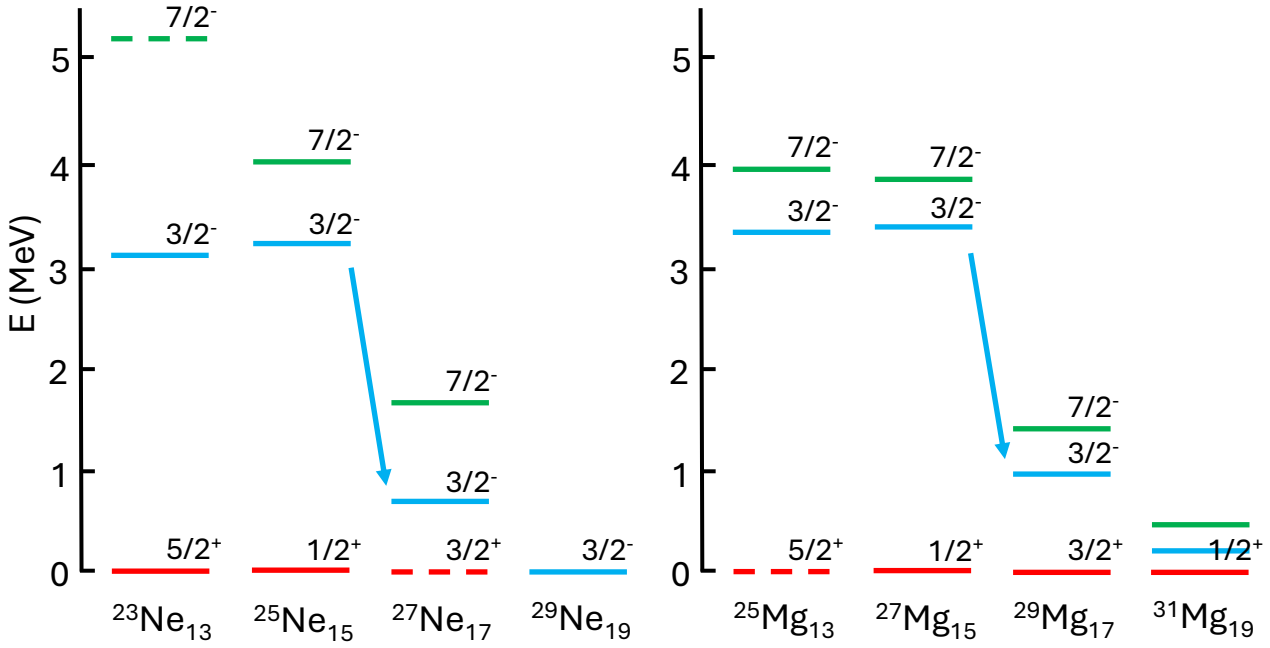

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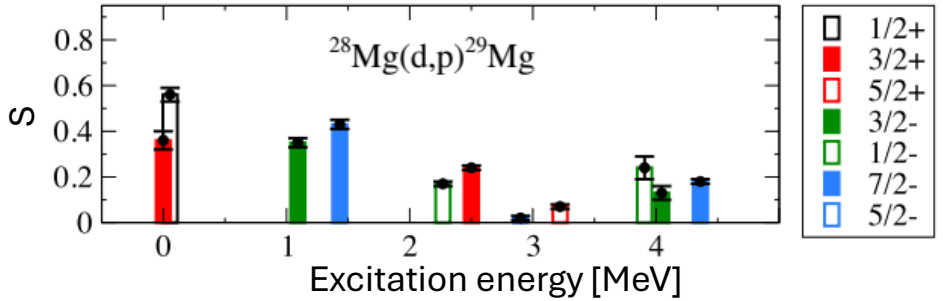

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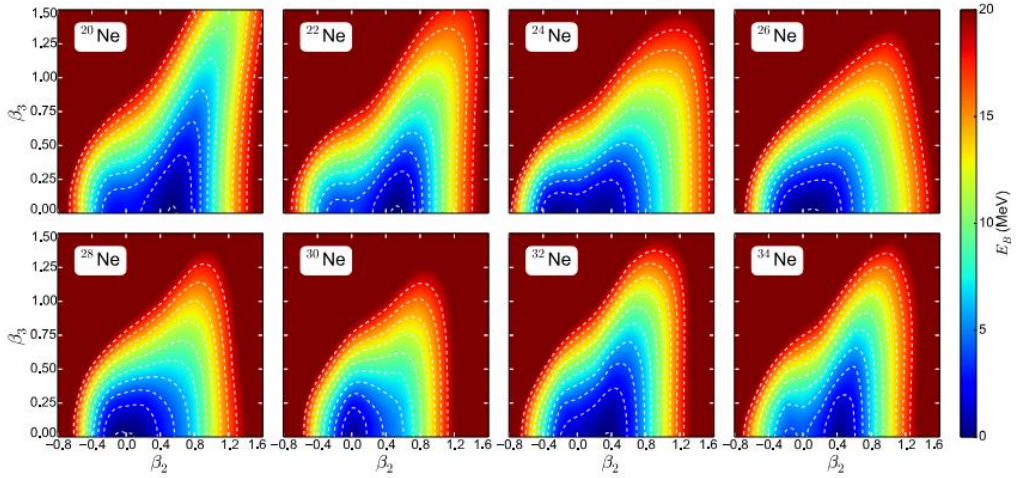
Quadrupole (2^+, 4^+) and octupole (3^-) collectivity



P. Marević et al., Phys. Rev. C 97, 024334, 2018

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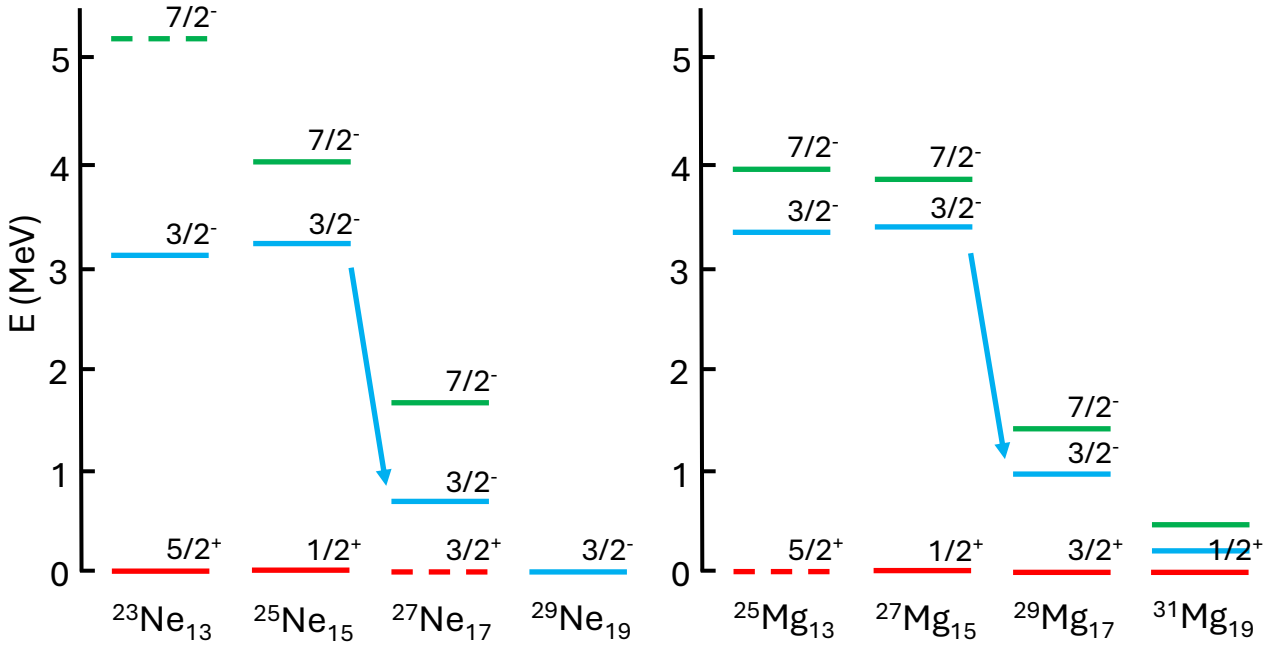

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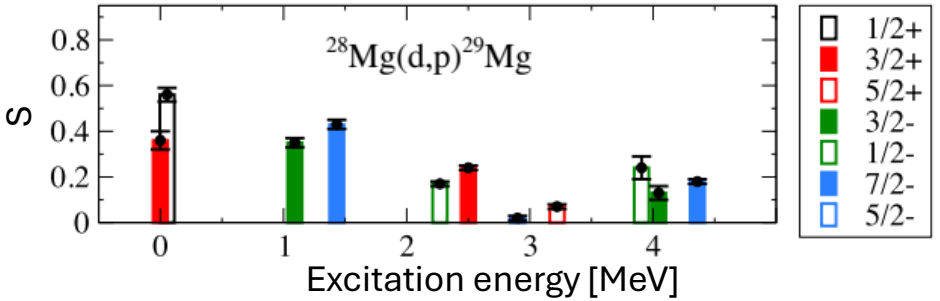

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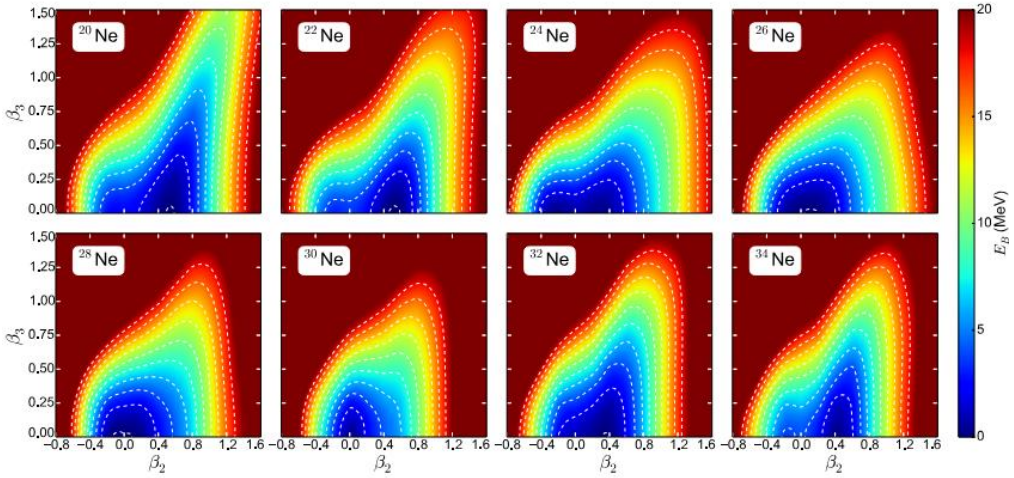

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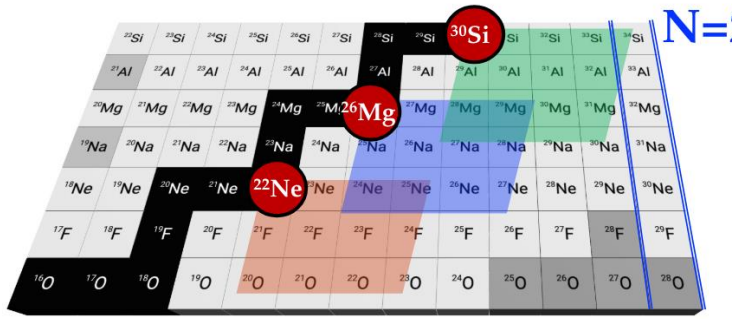
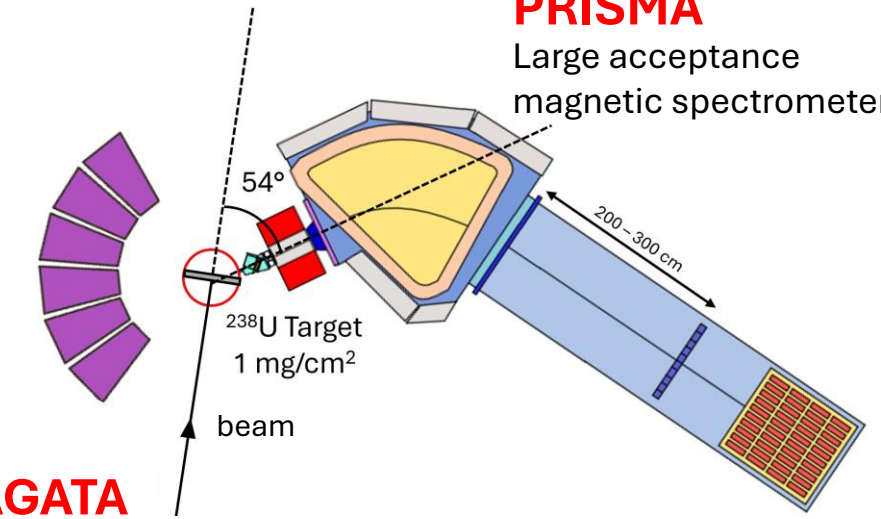
γ spectroscopy and lifetime measurements towards N = 20 Island of Inversion for $^{23\text{-}26}$Ne and $^{25\text{-}29}$Mg

Experimental campaign at LNL



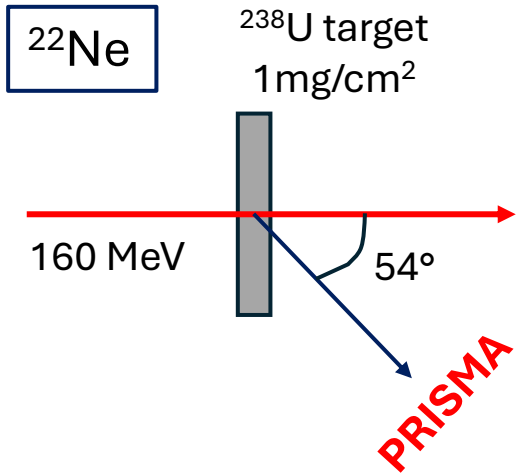
Described in Mid-Term Plan@LNL
M. Ballan et al., Eur. Phys. J. Plus 138, 709, 2023.



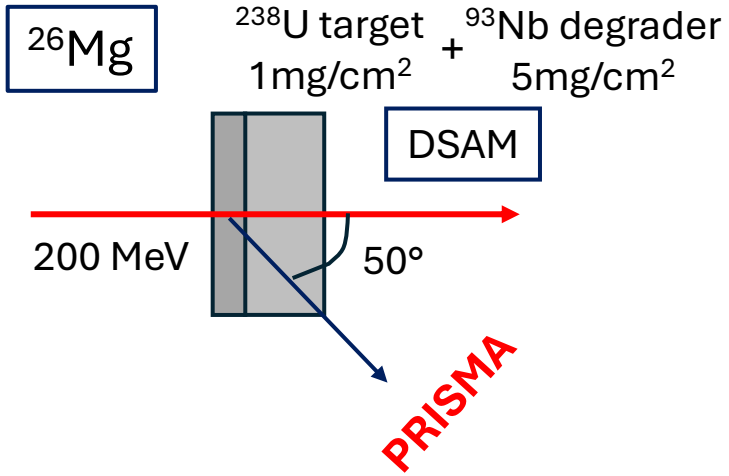
PRISMA
Large acceptance
magnetic spectrometer

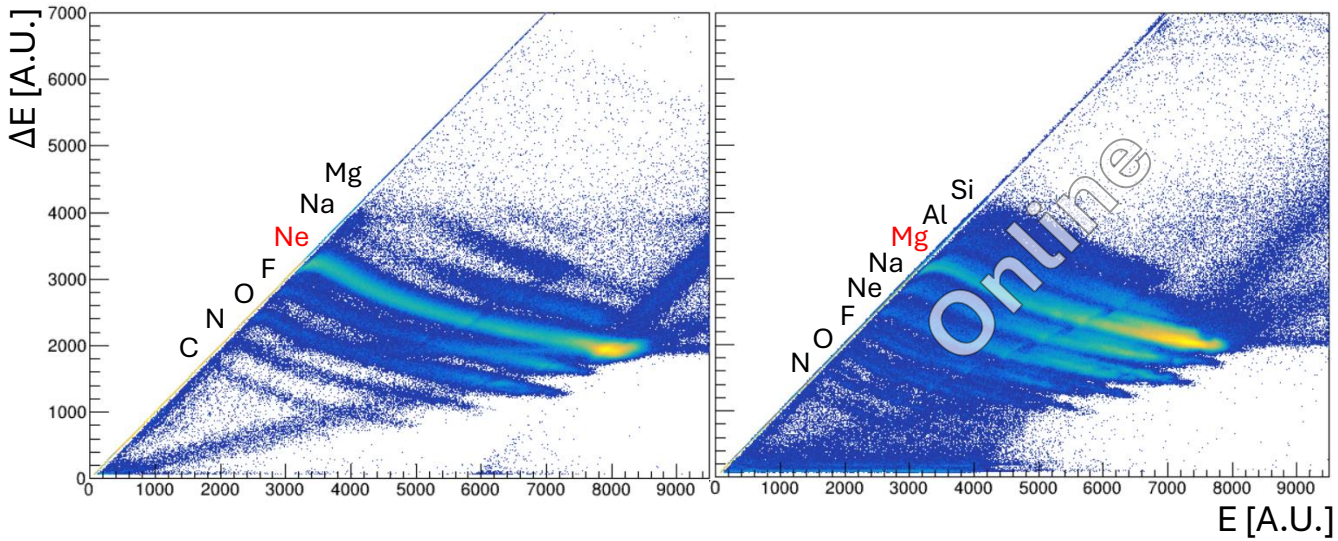
AGATA
High purity segmented germanium array
Detection efficiency ≈ 5.5% at 1 MeV

April 2023



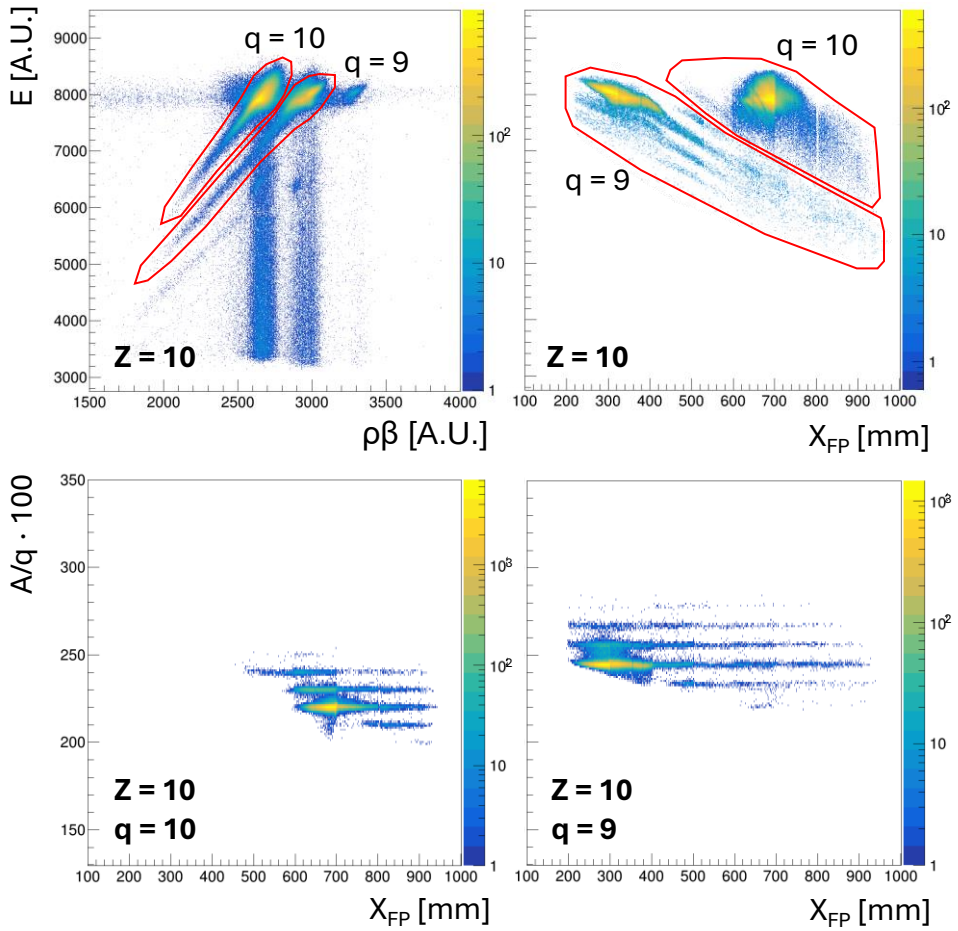
June 2024





PRISMA analysis ^{22}Ne + ^{238}U

Z and charge states selection



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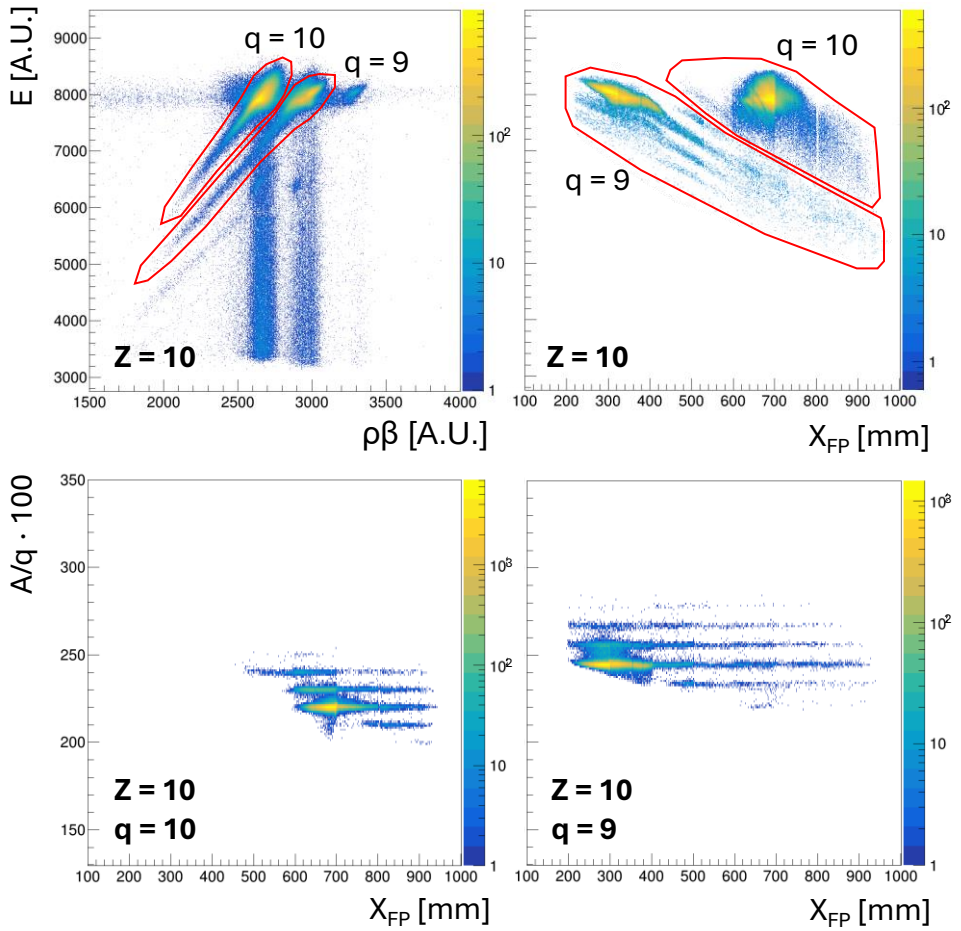
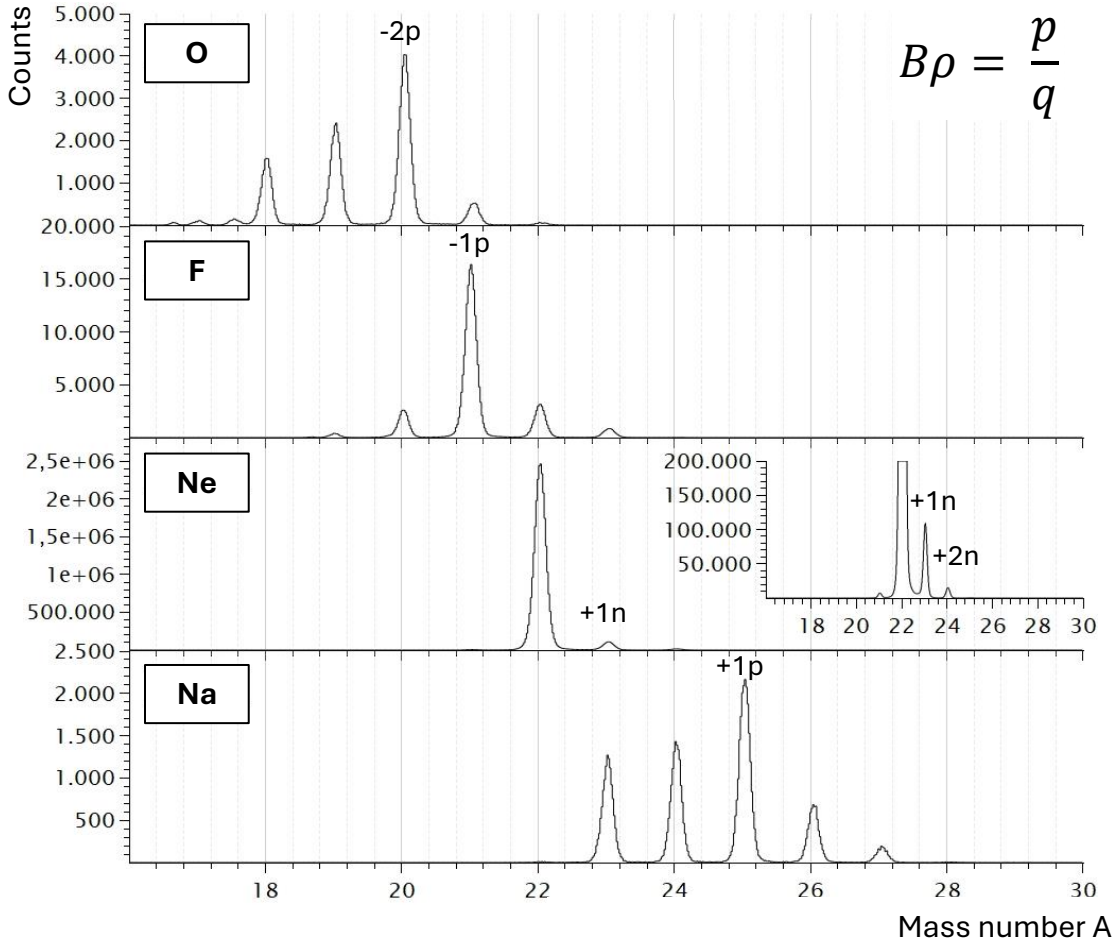
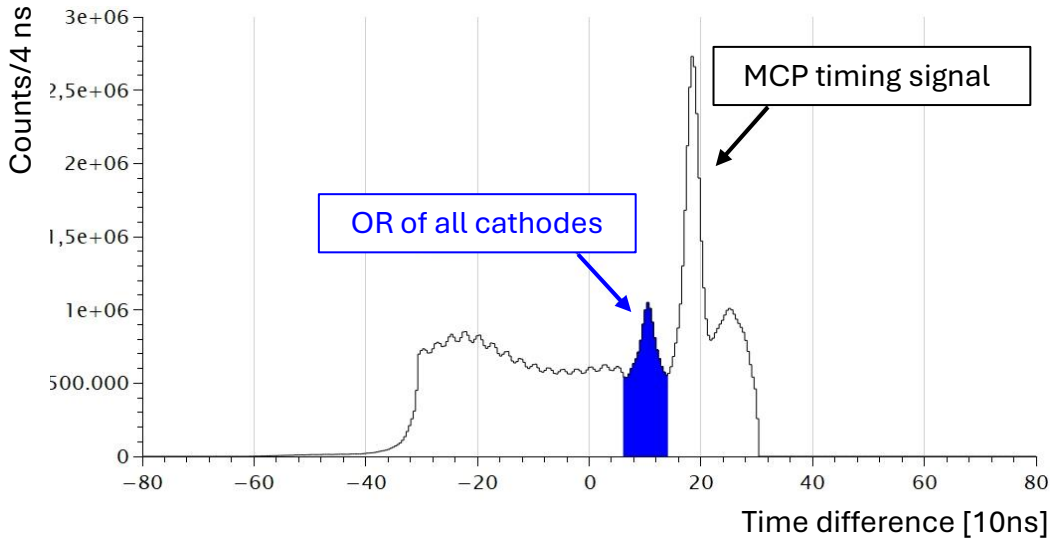


Mass distributions after trajectory reconstruction



AGATA – PRISMA coincidence ^{22}Ne + ^{238}U

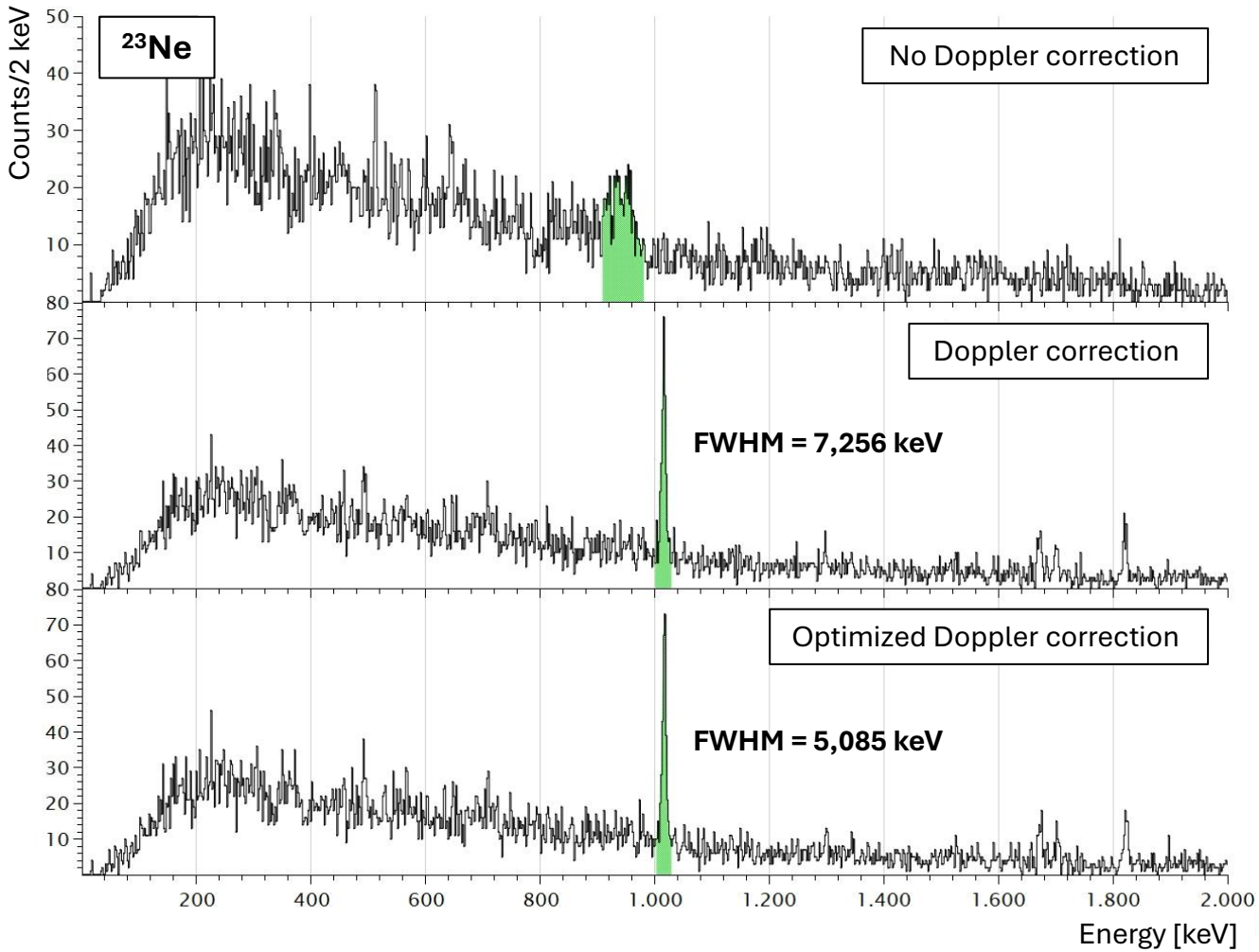


Trigger: **OR of all cathodes**
Time coincidence window: 90 ns

Doppler correction event by event + optimizer

$$E_\gamma = \frac{E_\gamma{}^0}{\gamma(1-\beta cos\theta)}$$

Energy resolution improvement **from 0,74% to 0,50%** at 1 MeV

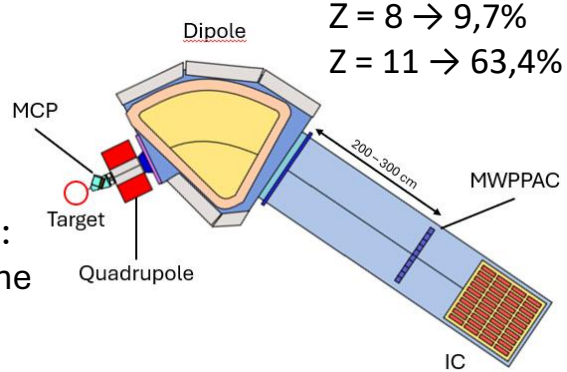


New PRISMA analysis $^{22}Ne + ^{238}U$

MWPPAC: Position on focal plane

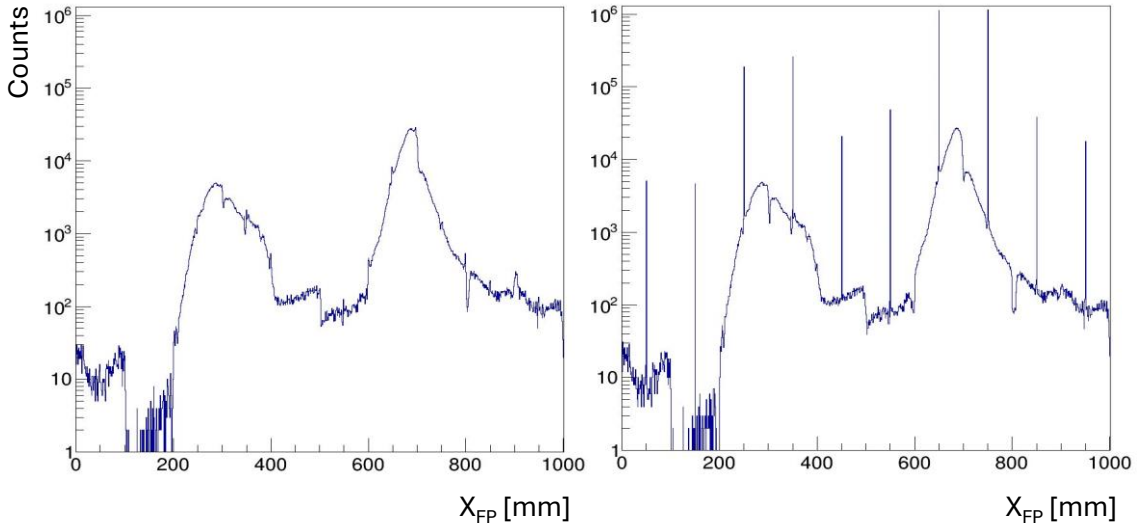
Low anodes efficiency for light nuclei (especially for low Z)

Z = 8 → 9,7%
Z = 11 → 63,4%



Accepting **cathode only signals**:

- Average position in focal plane
- Average β for Doppler correction



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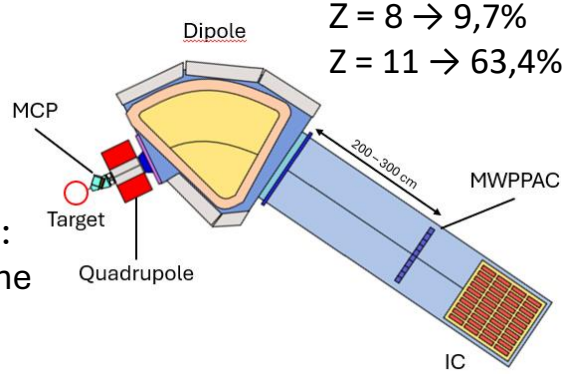
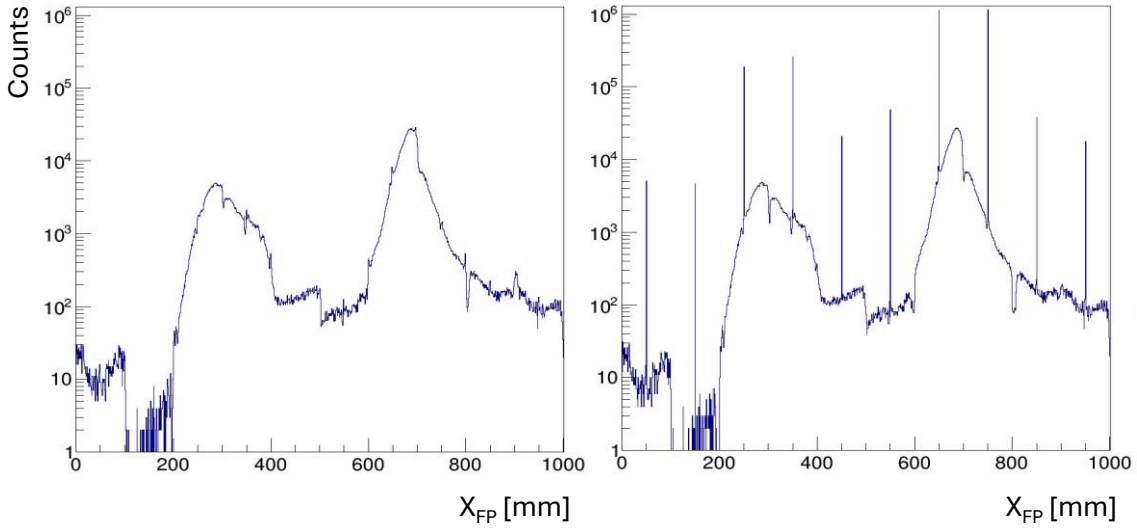
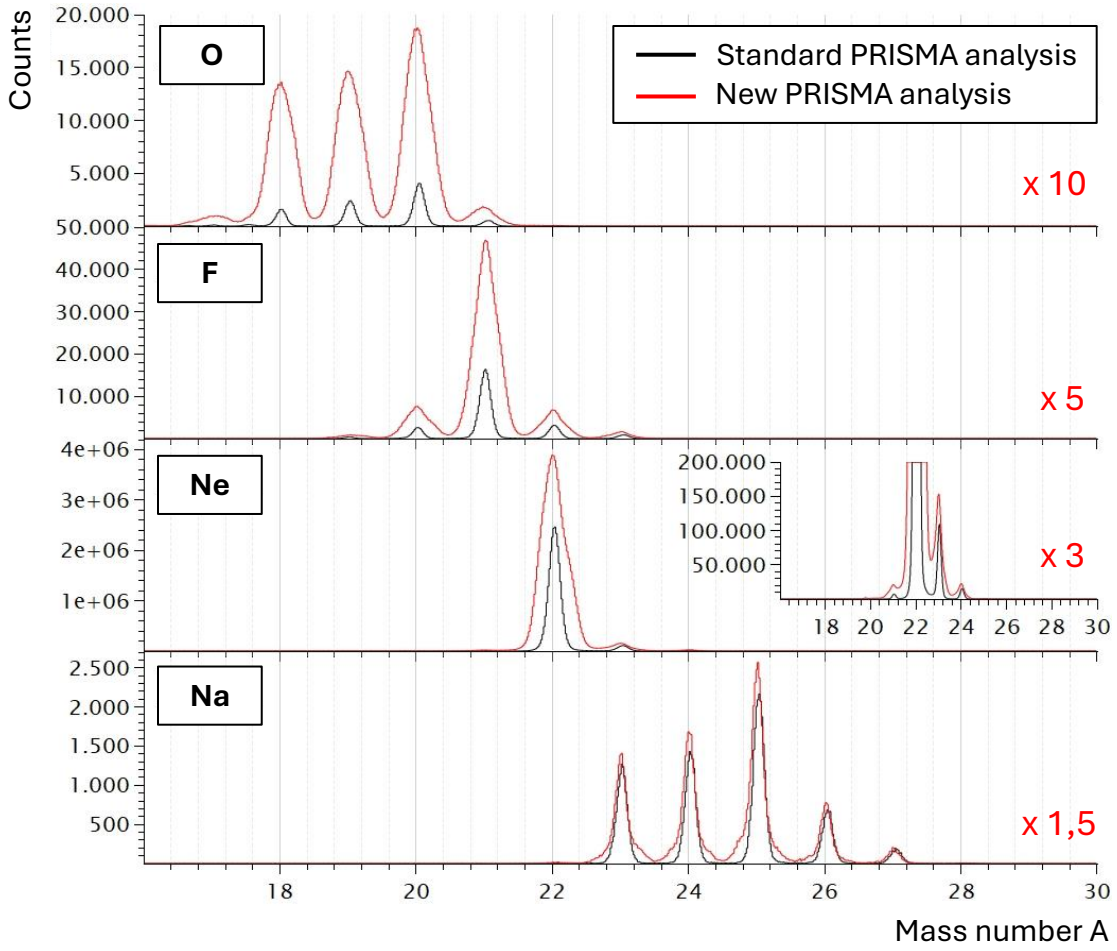




Mass distributions after trajectory reconstruction



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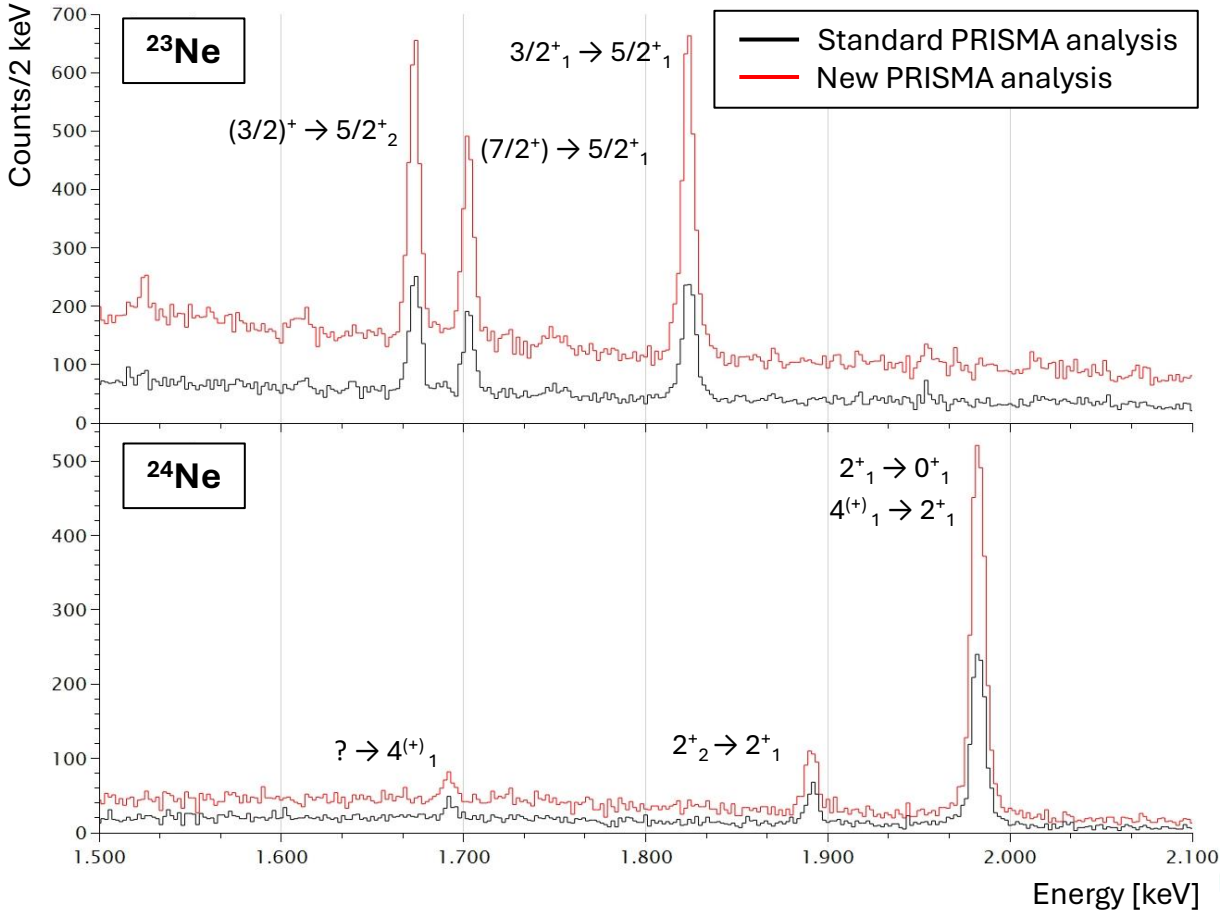
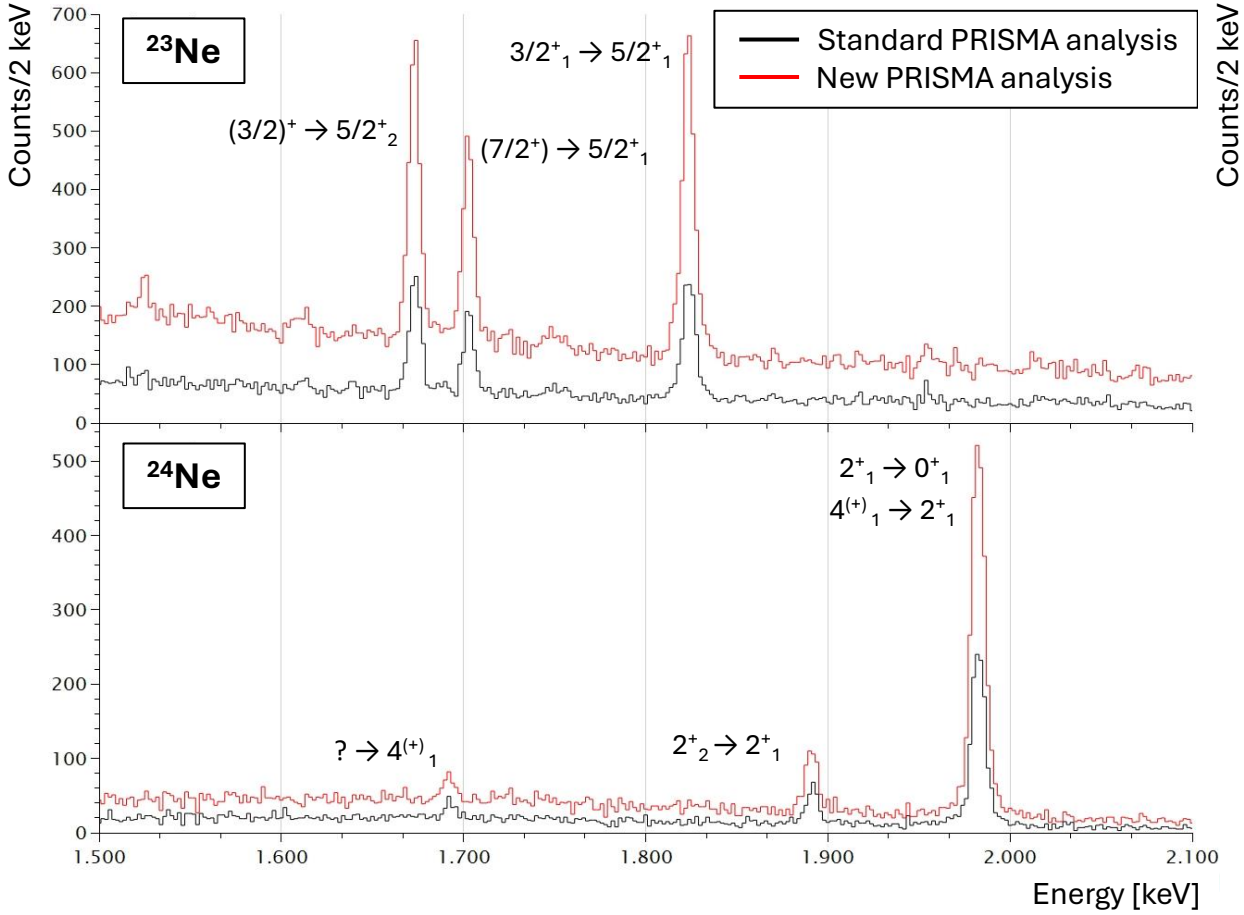
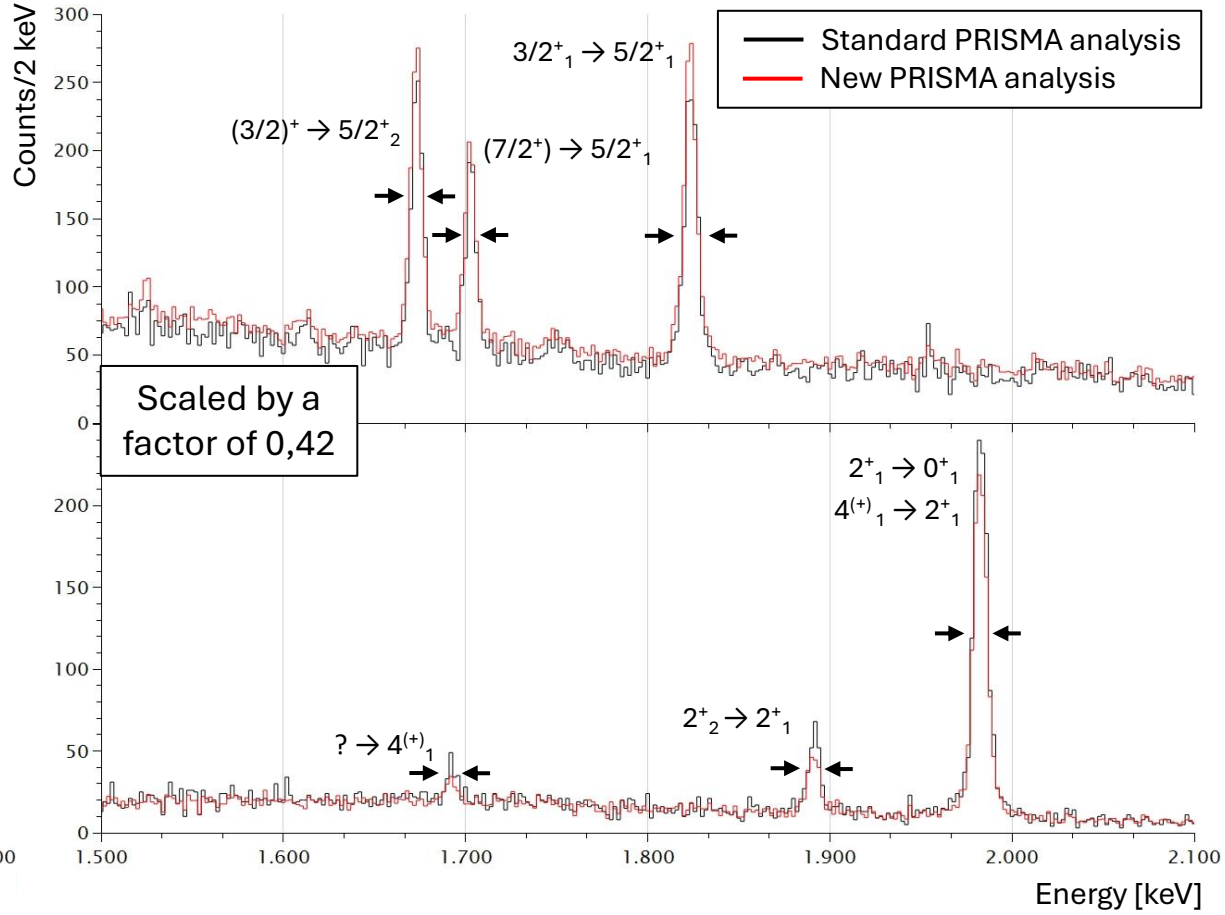


Increase in statistics by a factor of ≈ **2 - 2,8**

New PRISMA analysis $^{22}Ne + ^{238}U$



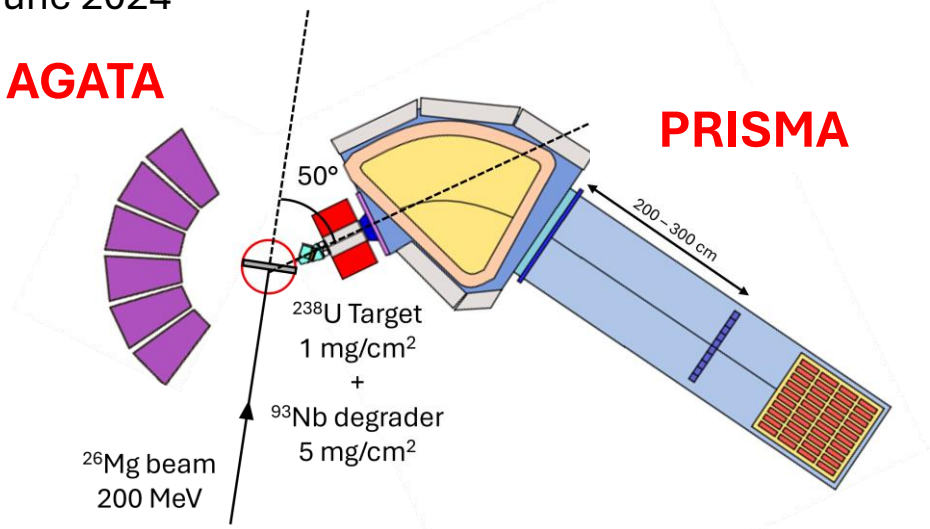


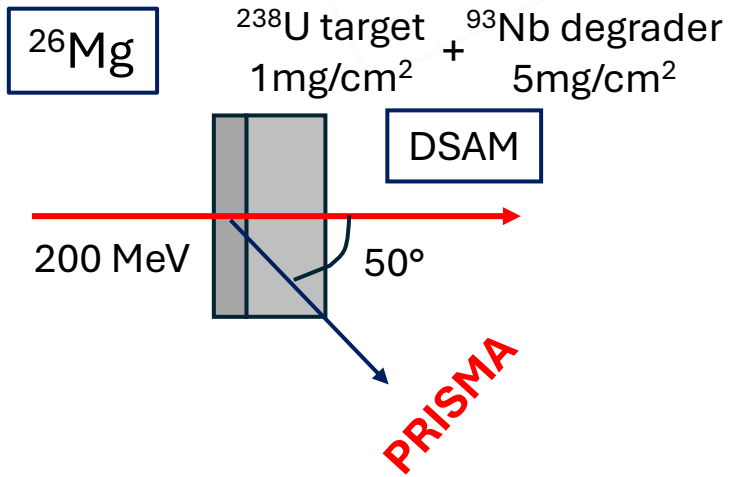
Increase in statistics by a factor of ≈ **2 - 2,8**

Energy resolution degradation ≈ **0,05 – 0,1%**

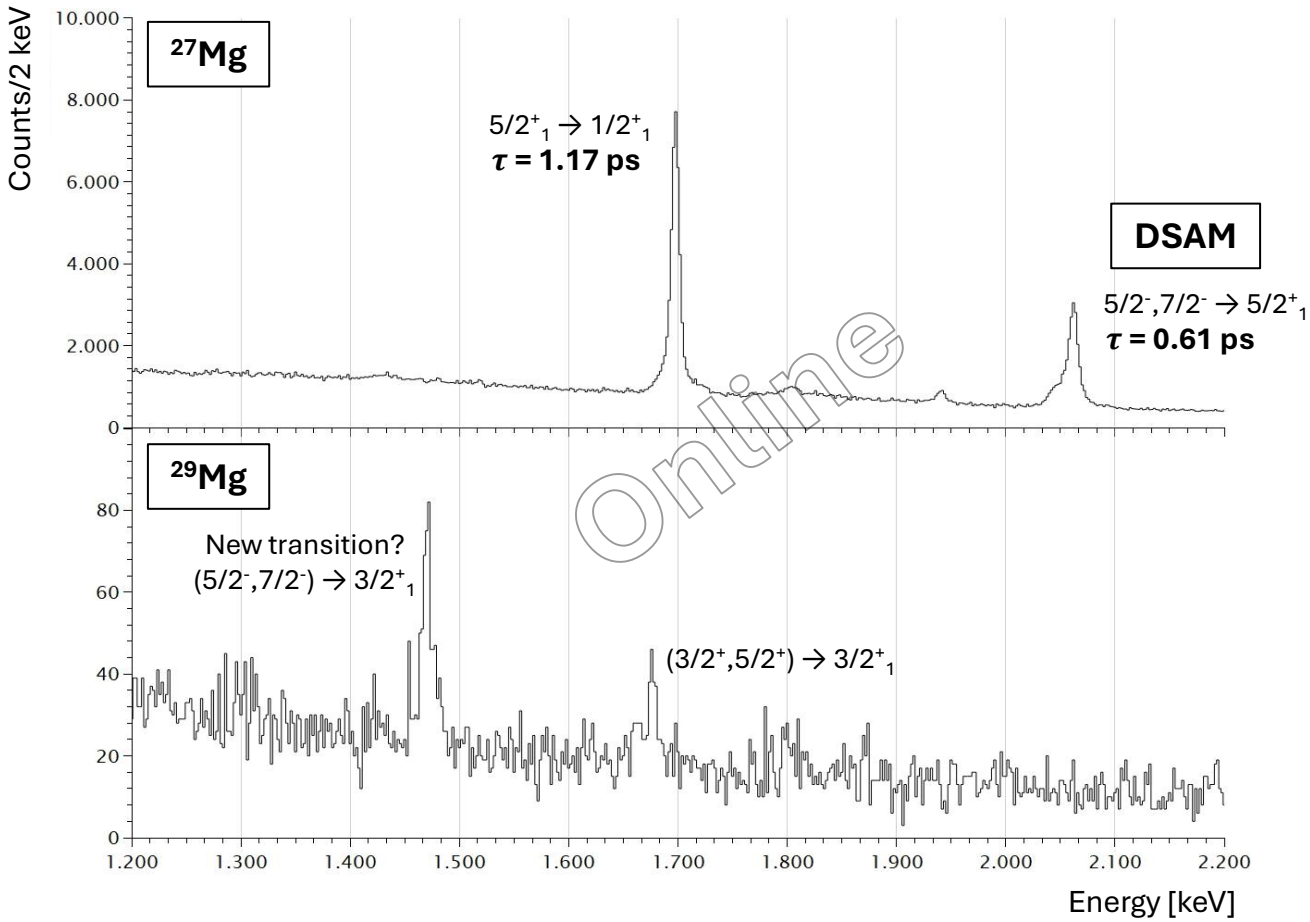
Experiment ^{26}Mg + ^{238}U

June 2024

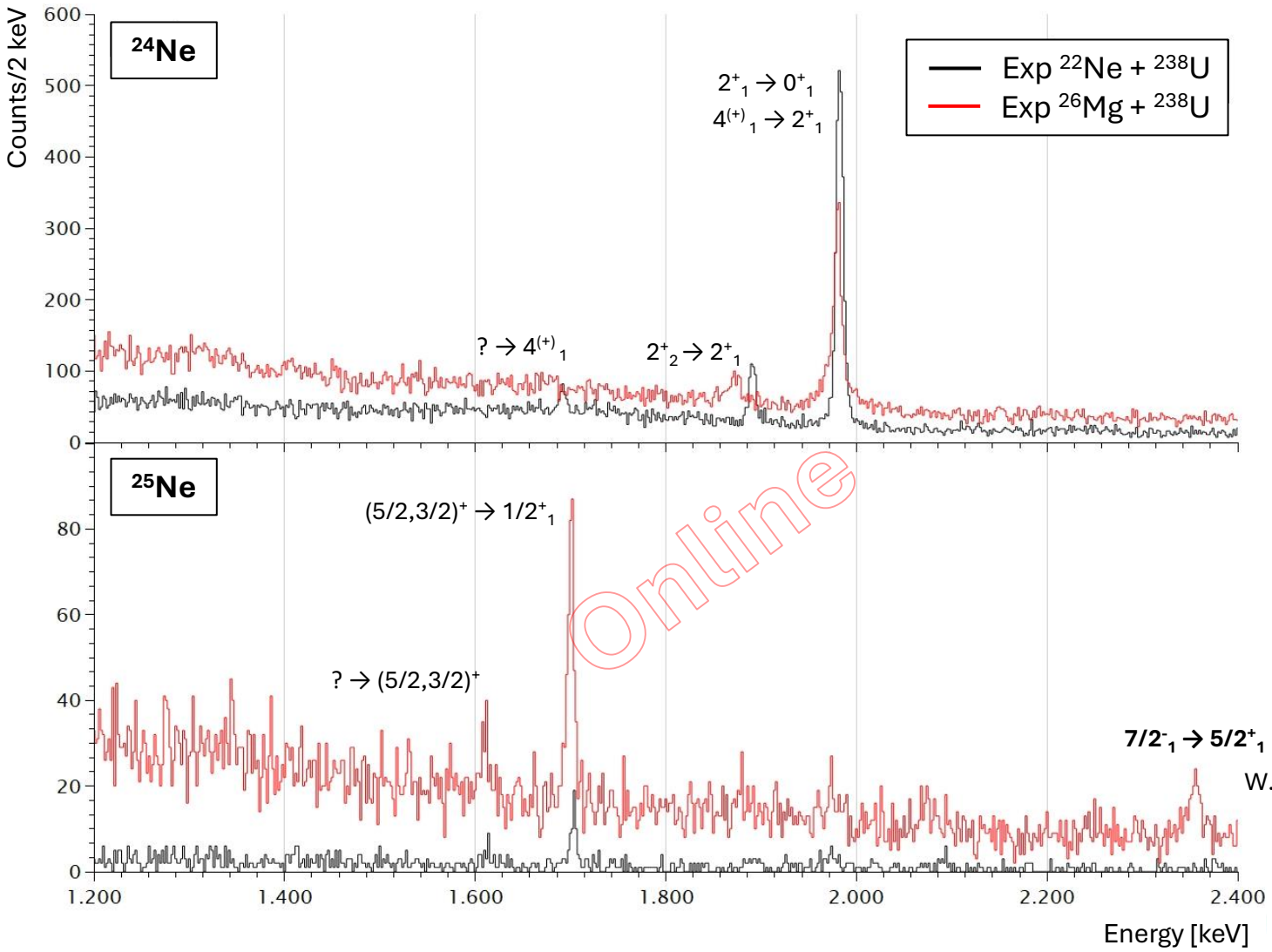




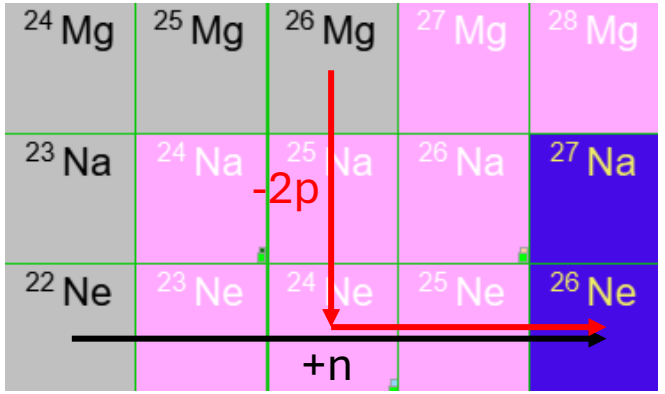
$$B(E/M\,\lambda) \propto \frac{1}{\tau} \qquad \tau \sim 10^1 - 10^3 \text{ fs}$$



Comparison: ^{22}Ne + ^{238}U and ^{26}Mg + ^{238}U



Ne isotopic chian (N = 12 – 16) produced by different transfer channels:



Different excited states population

W.N. Catford et al., Phys. Rev. Letters, 104, 192501, 2010

Conclusion

Nuclear structure of light isotopes approaching the Island of Inversion at N = 20 is now being probed using ^{22}Ne + ^{238}U and ^{26}Mg + ^{238}U MNT reactions employing the AGATA-PRISMA spectrometer, within the Mid Term Plan of Laboratori Nazionali di Legnaro.

M. Ballan et al., Eur. Phys. J. Plus 138, 709, 2023.

The analysis is focused on γ spectroscopy and lifetime measurements of excited states of the - mostly unexplored - Ne and Mg isotopic chains with N = 12 – 18.

A new analysis technique to overcome inefficiency in the PRISMA focal plane detector was developed and implemented, allowing to recover statistics by a factor between 100% to 200%, without a significant worsening of the resolution both in masses and energy spectra.

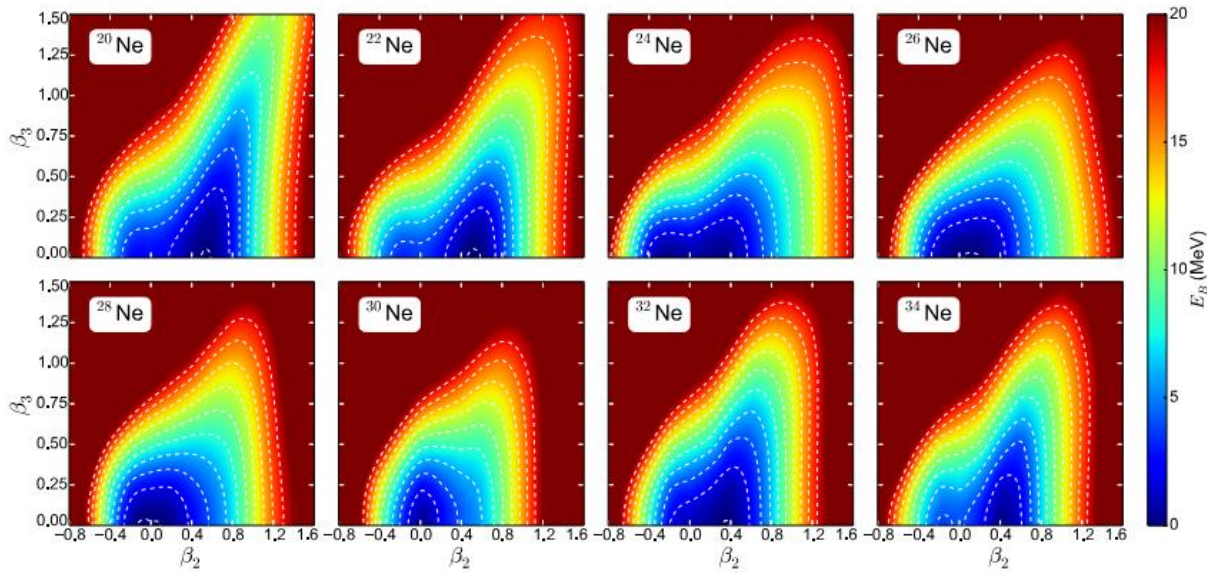
Future perspectives

- γ decay level schemes will be reconstructed for $^{23\text{-}26}$Ne and $^{25\text{-}29}$Mg;
- Lifetime measurements of excited states of these nuclei will be performed using the Doppler Shift Attenuation Method;
- Excitation energies and EM transition rates will be used to benchmark state-of-the art theoretical models;
- Comparison of the results of two data runs.

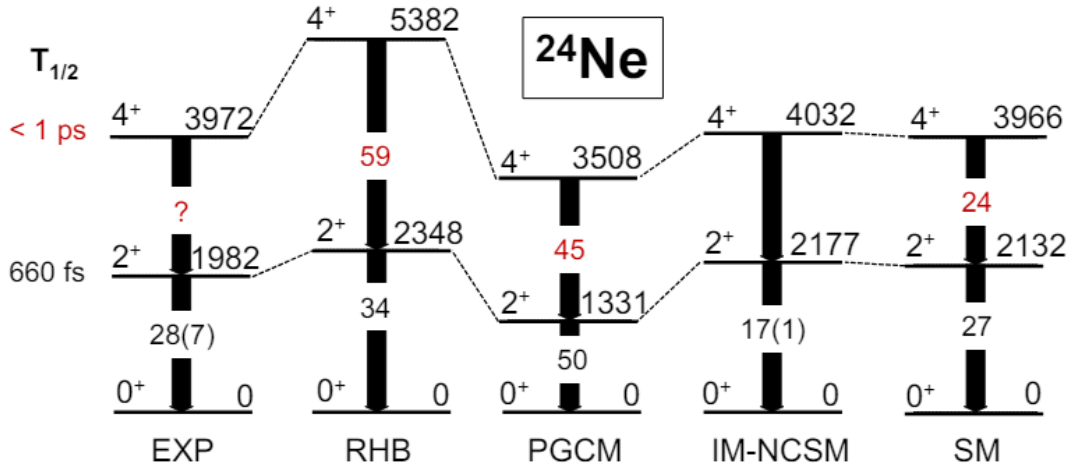
Thank you for the attention!

Physics case: Island of Inversion at N = 20 (back-up)

Quadrupole (2^+, 4^+) and octupole (3^-) collectivity



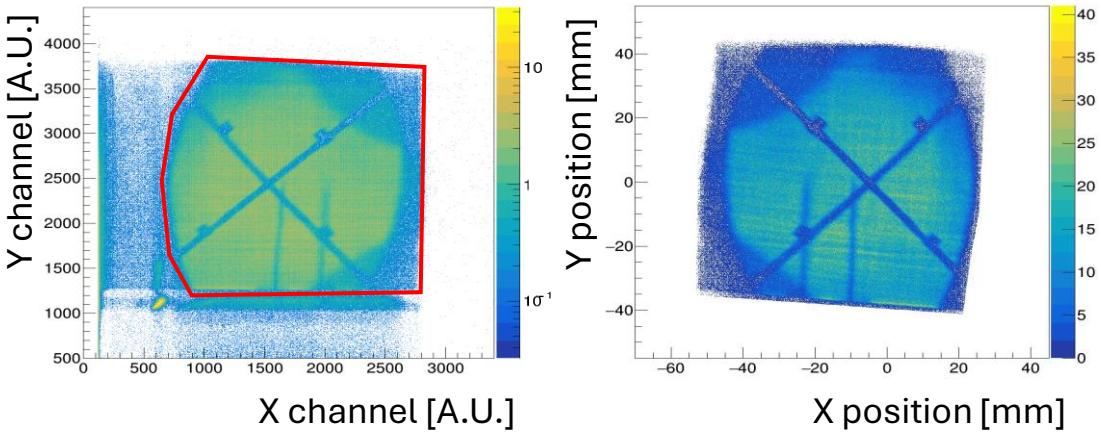
P. Marević et al., Phys. Rev. C 97, 024334, 2018



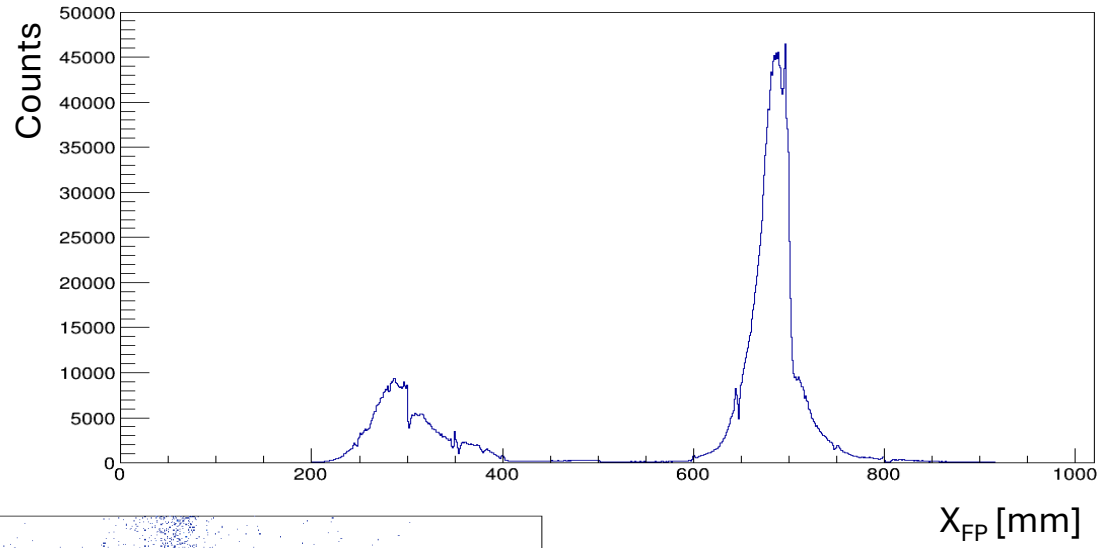
M. Frosini et al., Eur. Phys. J. A, 58:63, 2022

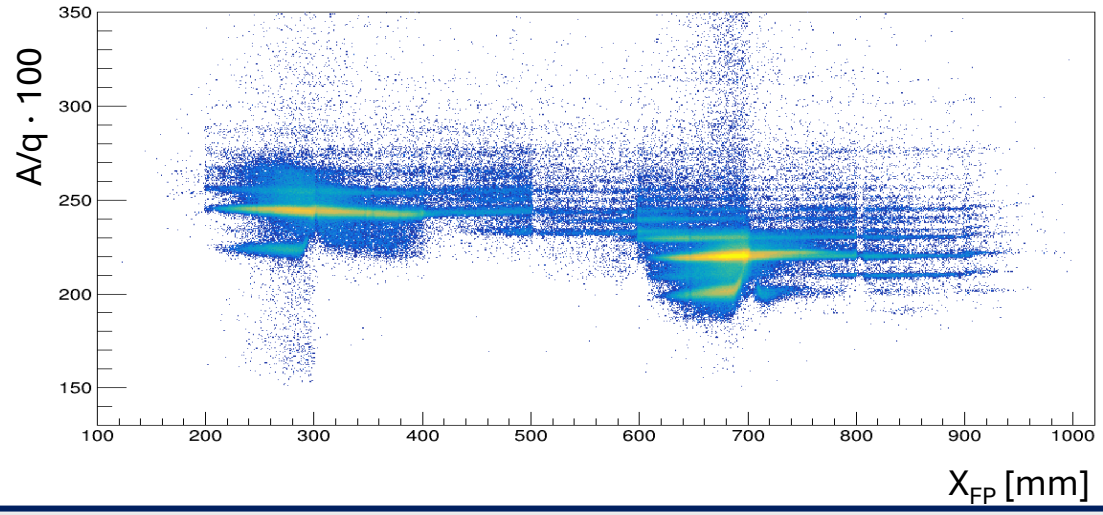
PRISMA analysis ^{22}Ne + ^{238}U (back-up)

MCP calibration



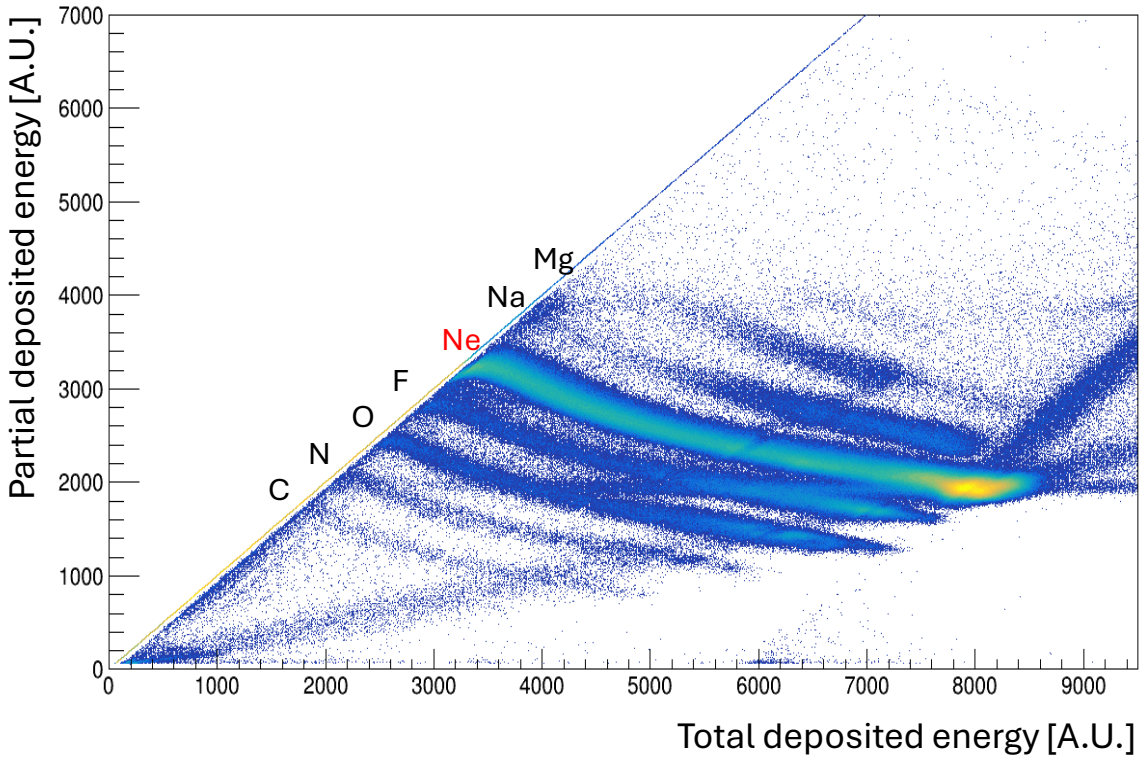
MWPPAC position at focal plane



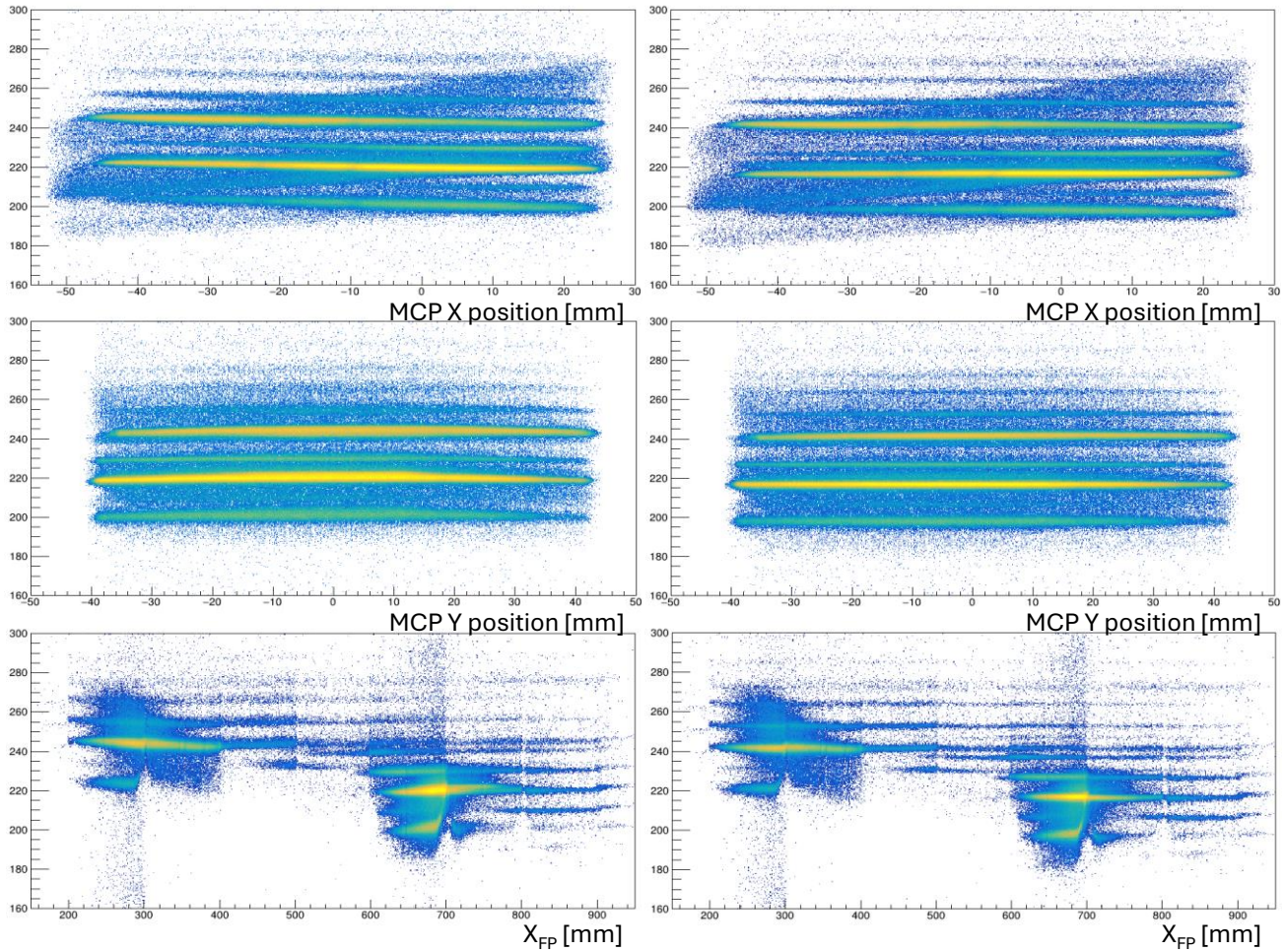


PRISMA analysis ^{22}Ne + ^{238}U (back-up)

Z selection

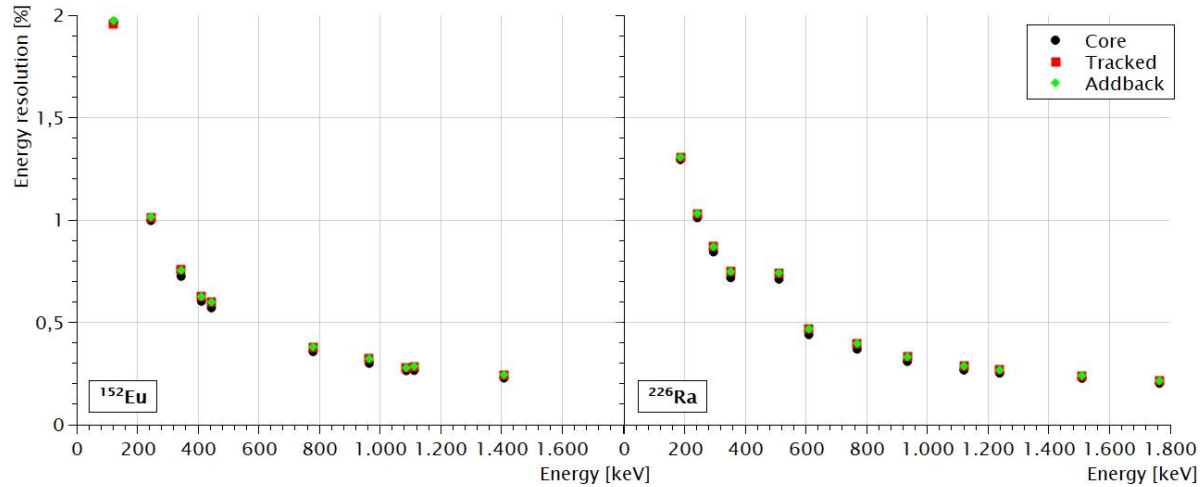


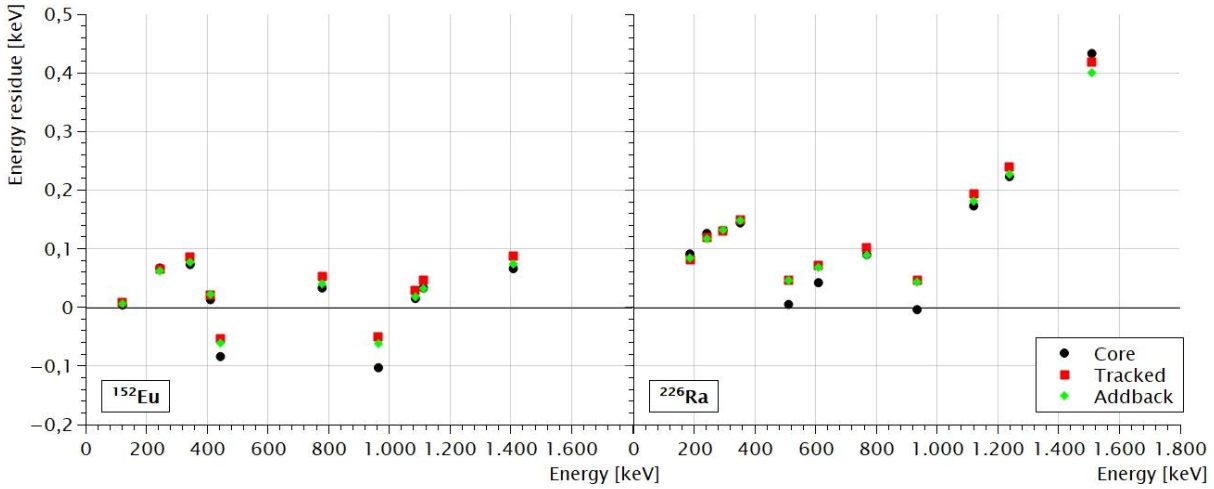
Aberrations correction



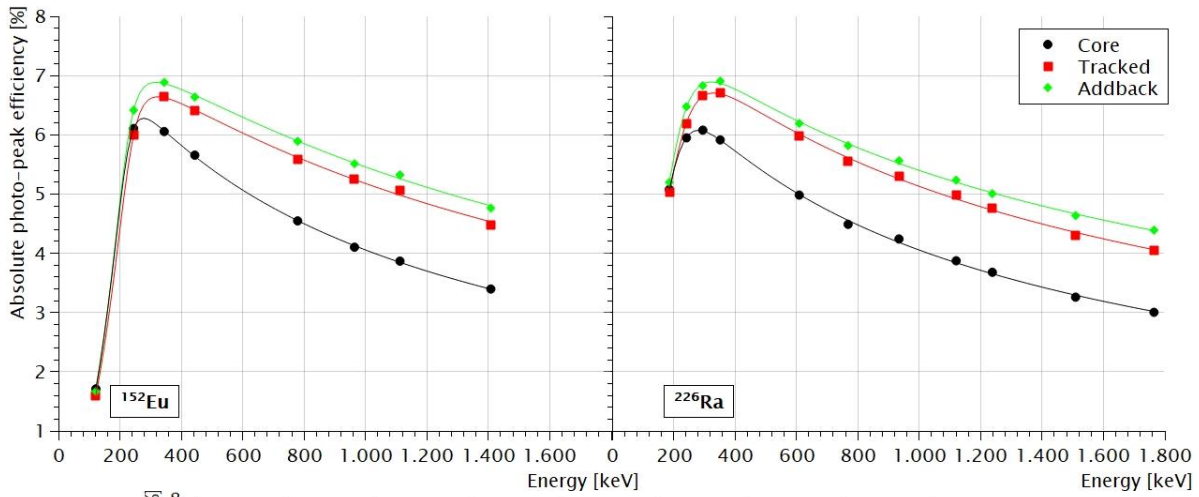
AGATA analysis ^{22}Ne + ^{238}U (back-up)

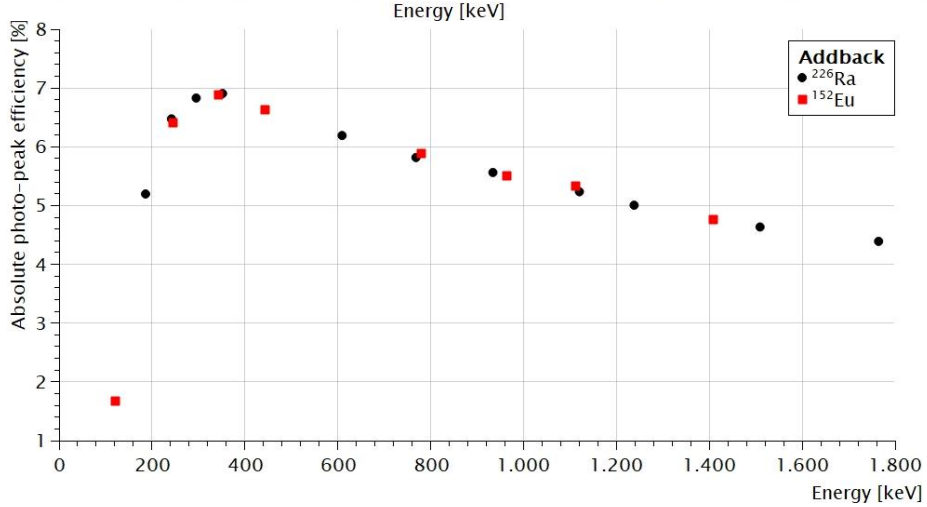
Energy resolution





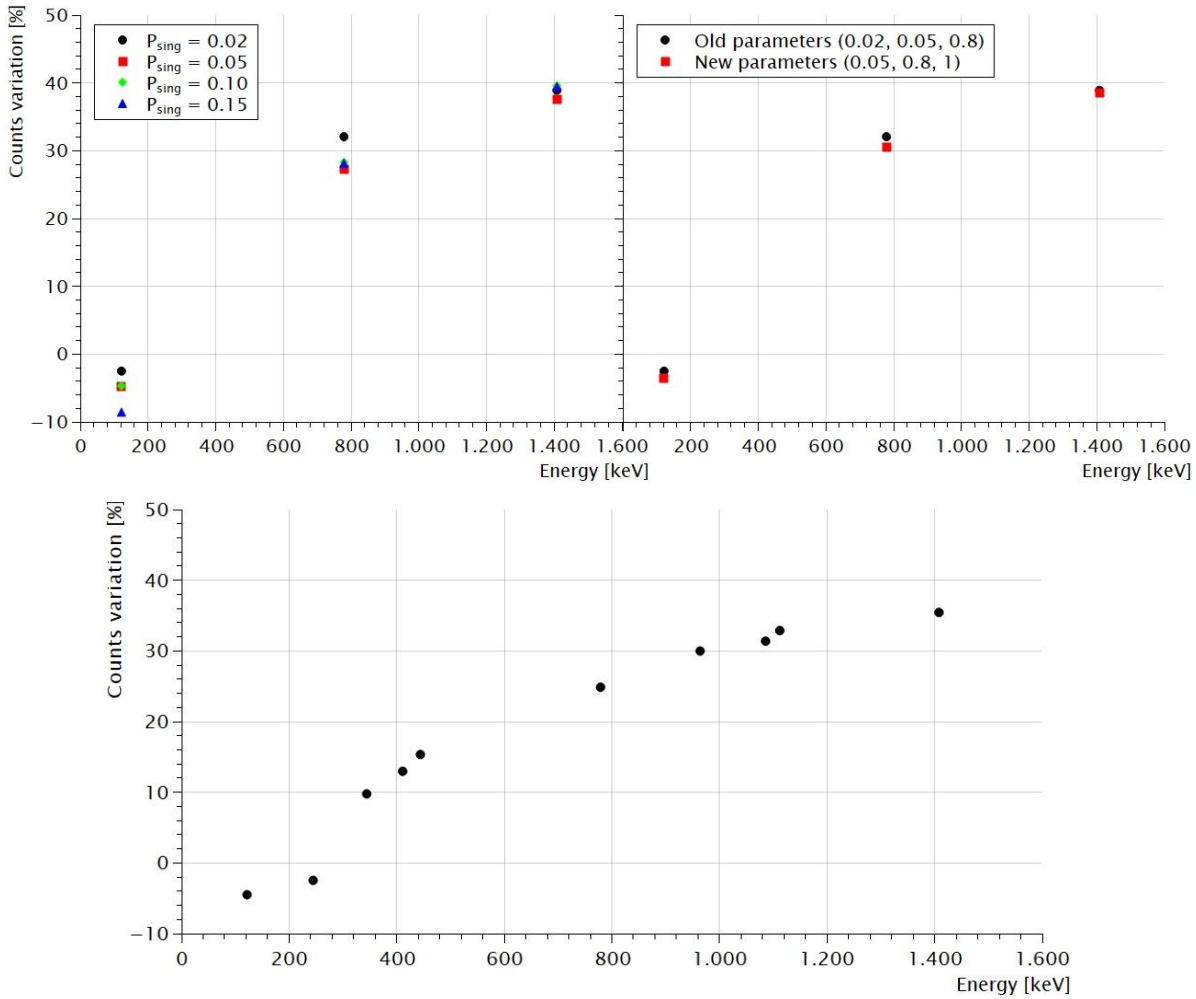
Absolute efficiency

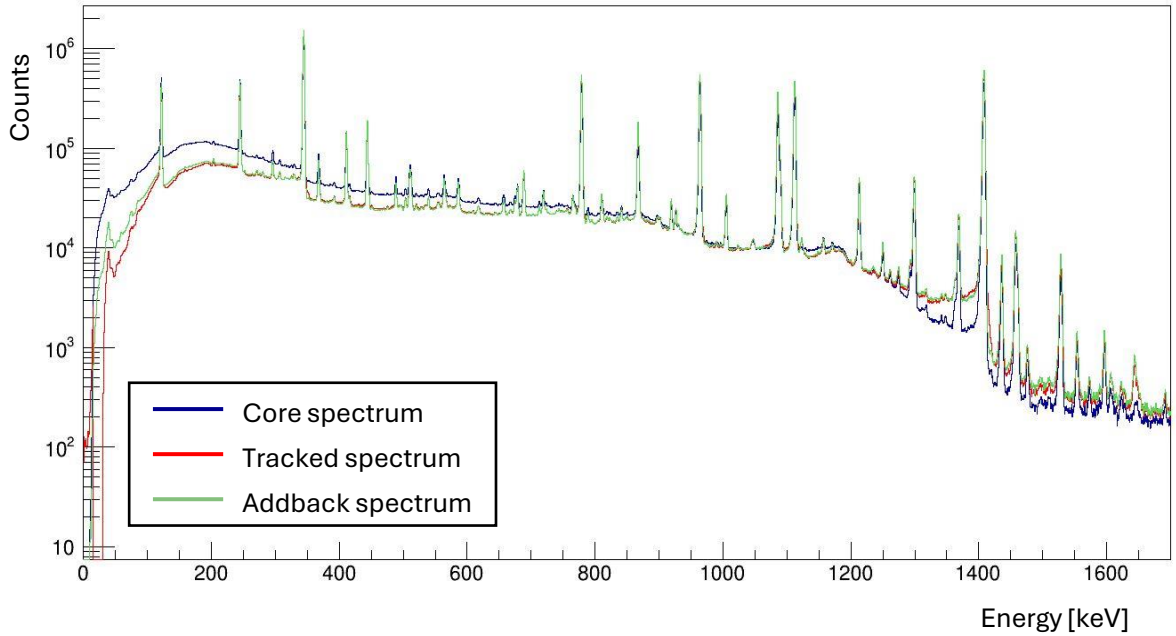




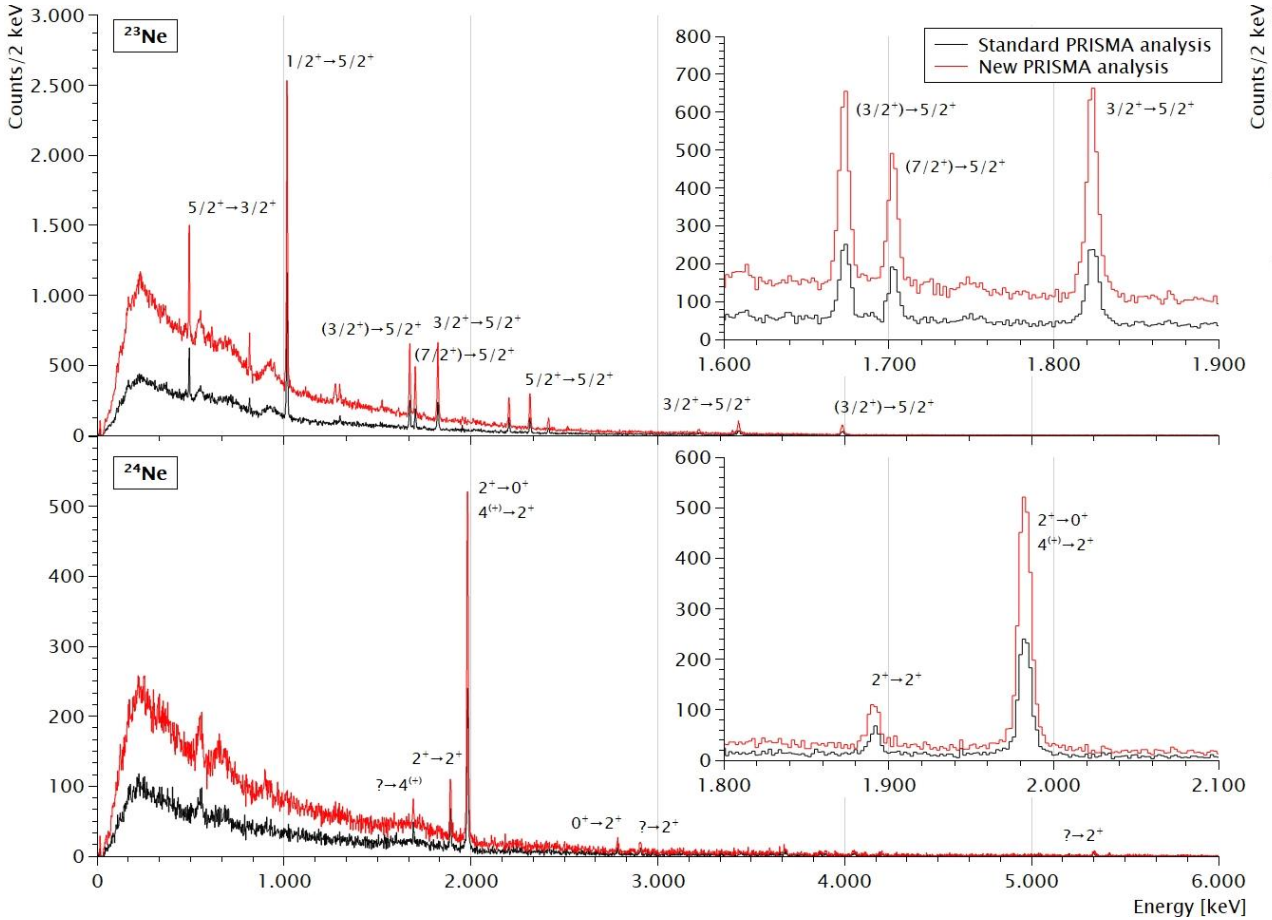
AGATA analysis ^{22}Ne + ^{238}U (back-up)

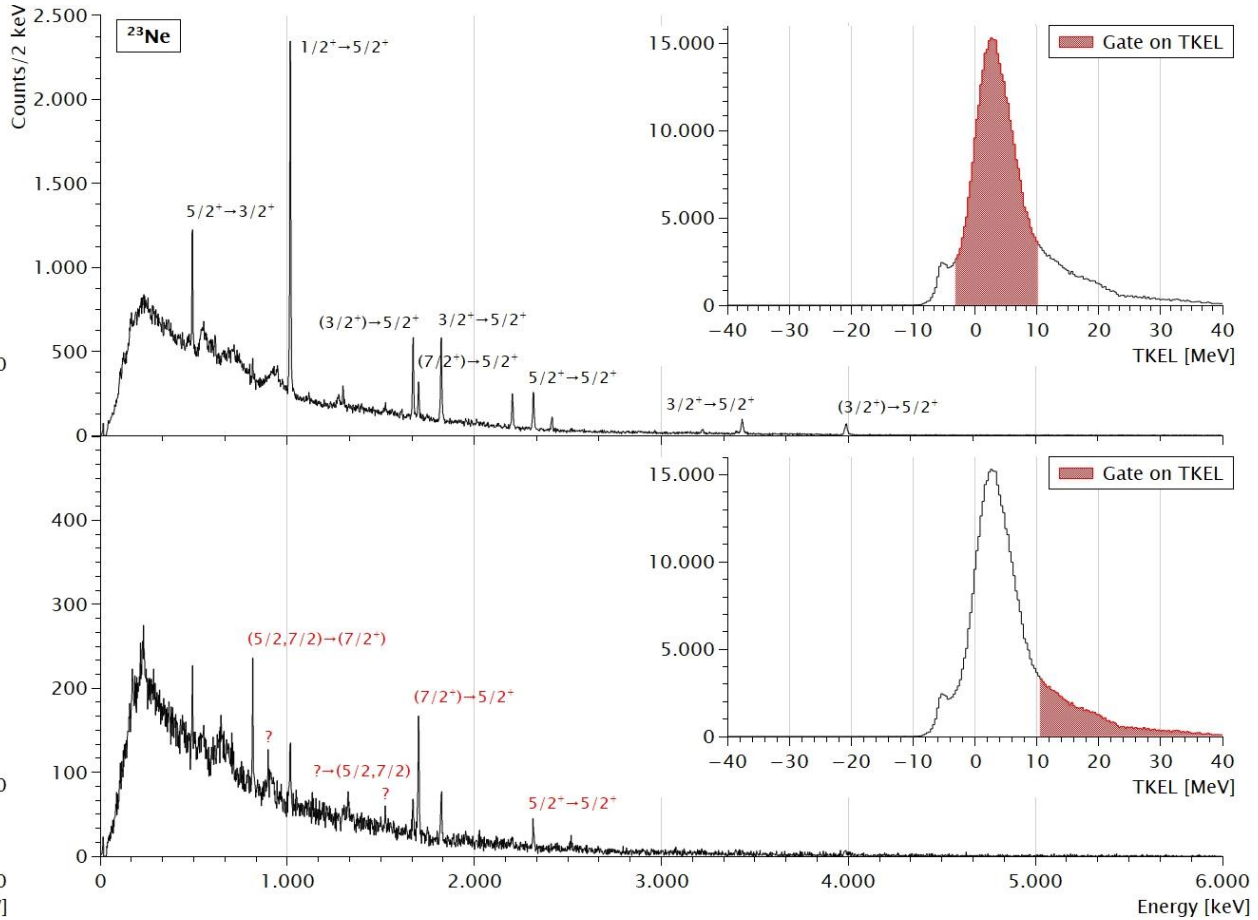
Tracking optimization





AGATA – PRISMA coincidence ^{22}Ne + ^{238}U (back-up)





New PRISMA analysis $^{22}Ne + ^{238}U$ (back-up)