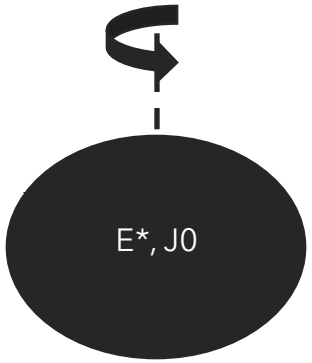
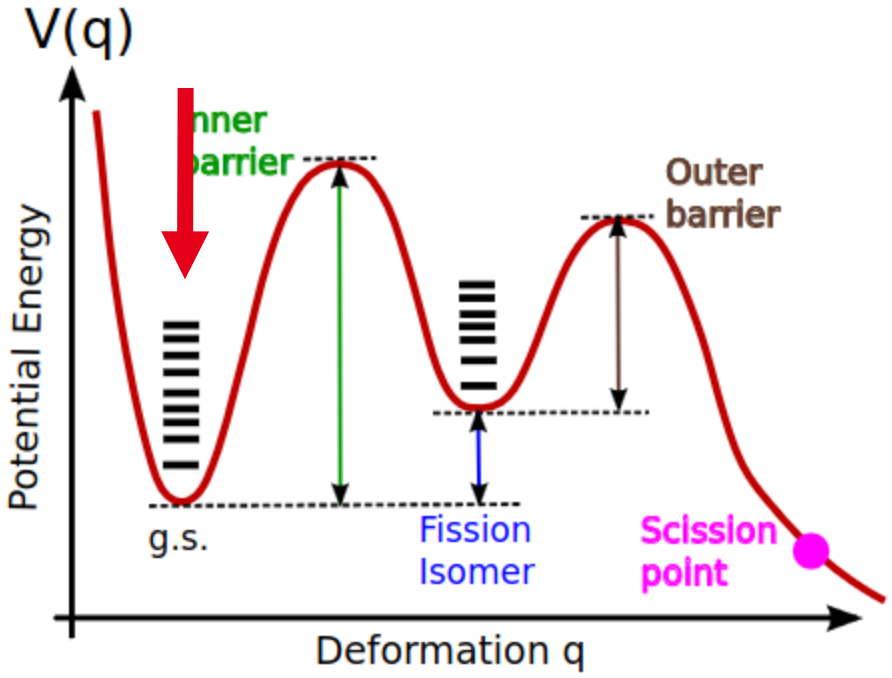
Probing fission fragments spin distribution from $^{238}U + ^{9}Be \rightarrow ^{247}Cm^{*}$ using AGATA & VAMOS++

Jonathan Bequet (GANIL)

Colloque GANIL 2026

Motivation: A modern probe of fission dynamics?





N. Shunck and D. Shunk. "Theory of Nuclear Fission". In: Progress in Particle and Nuclear Physics 125 (2022)

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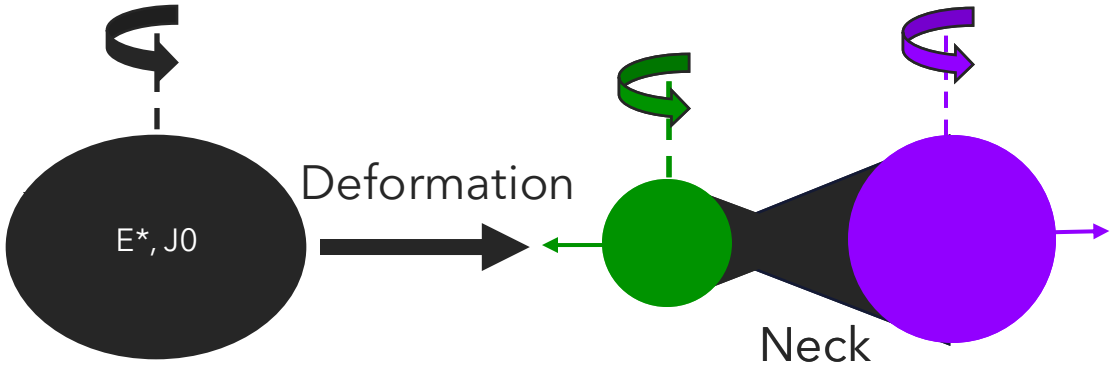

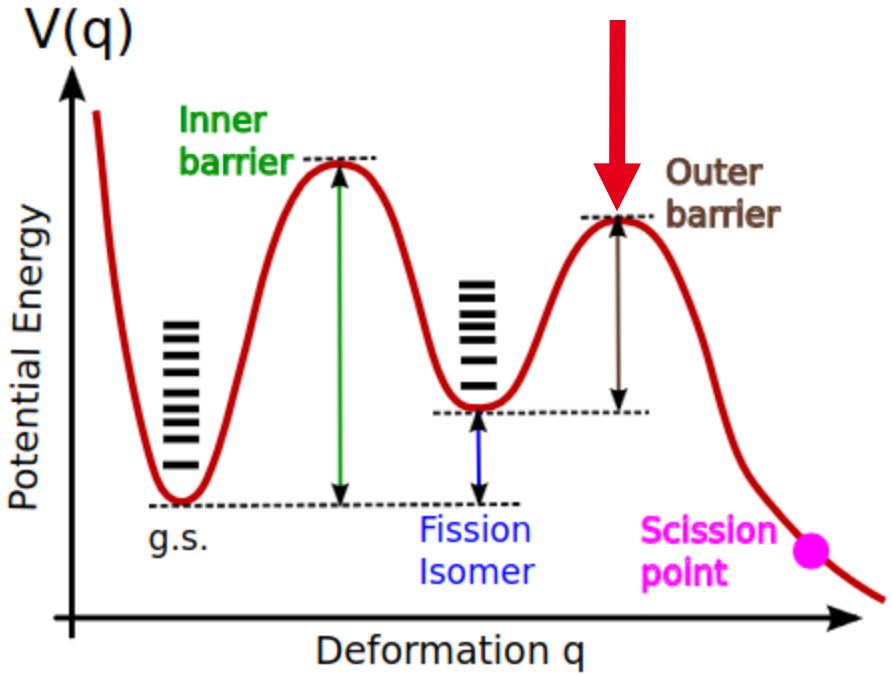

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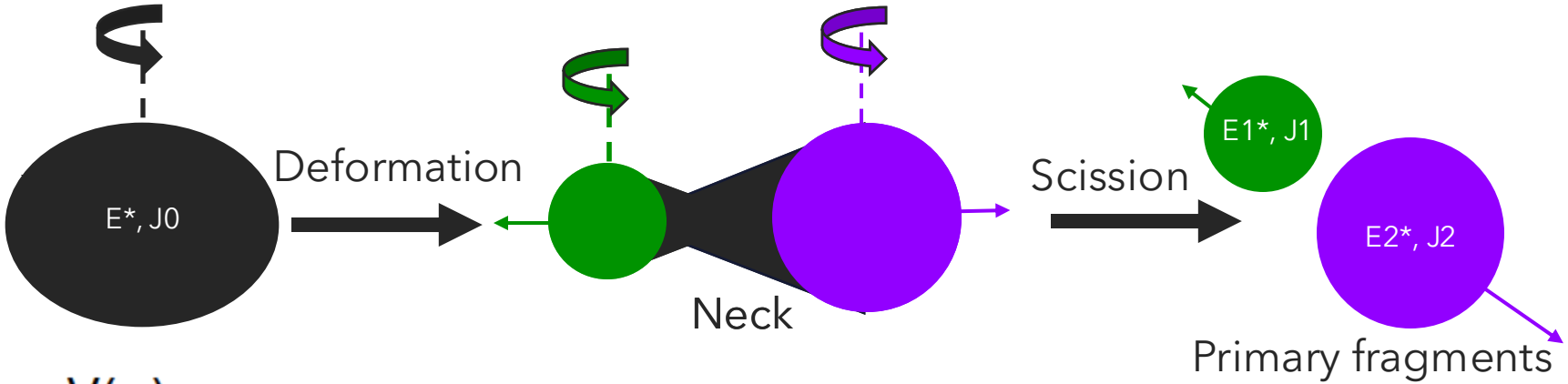

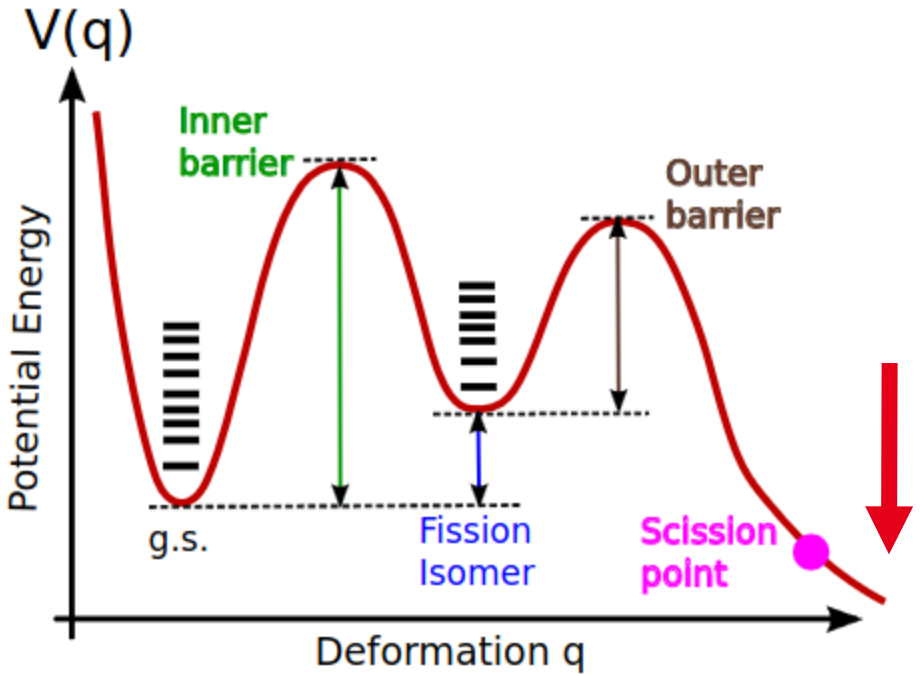

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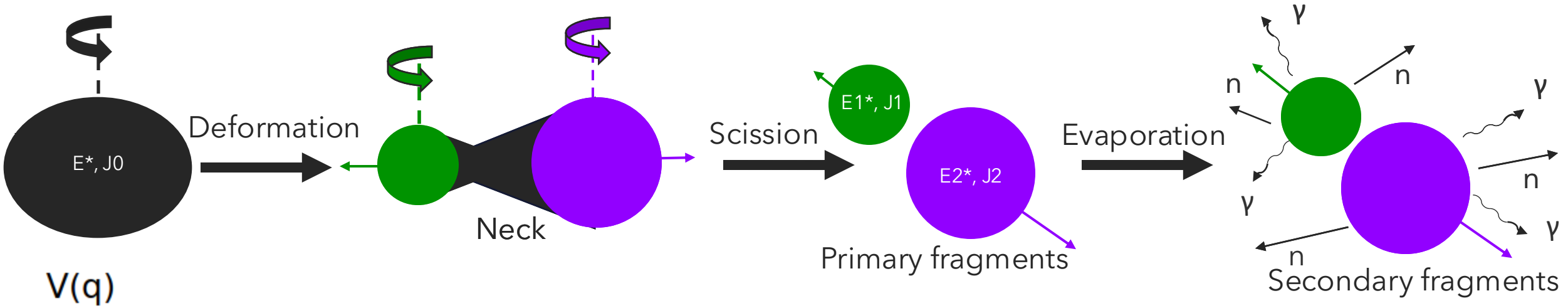

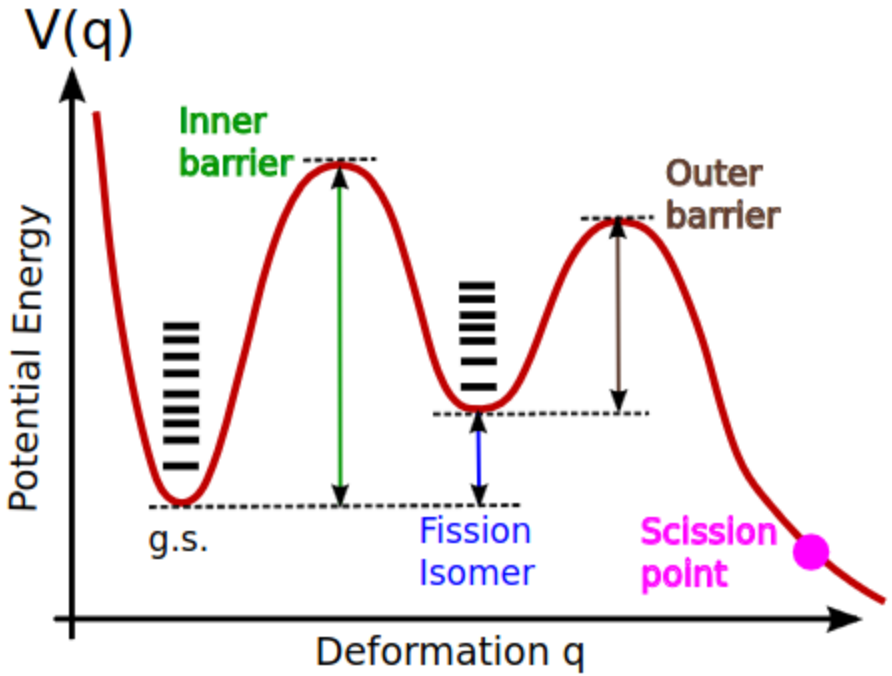

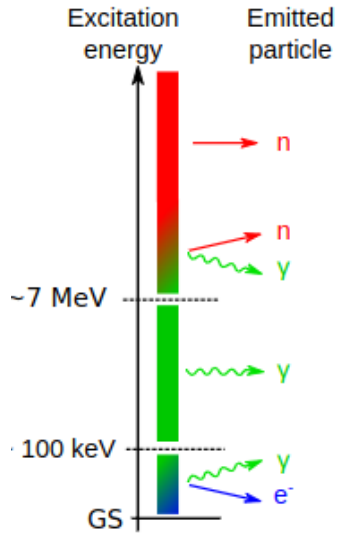

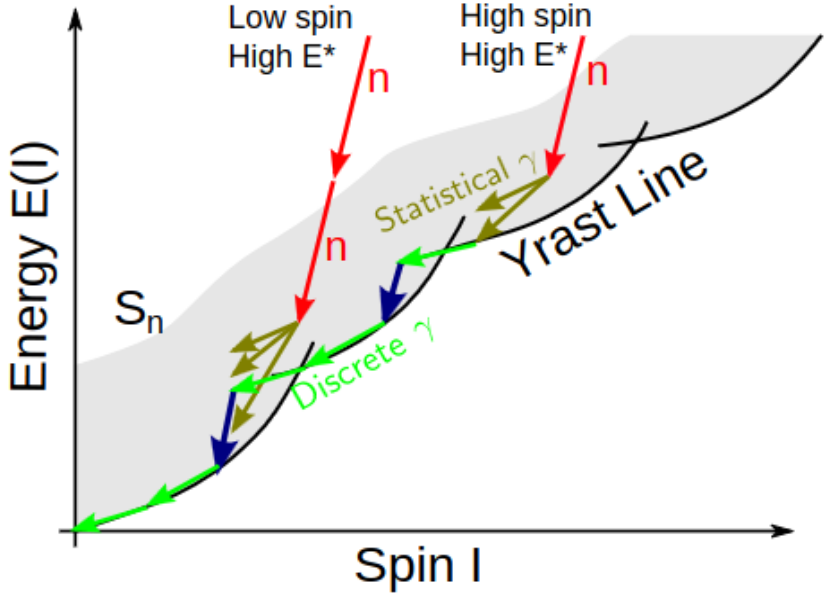

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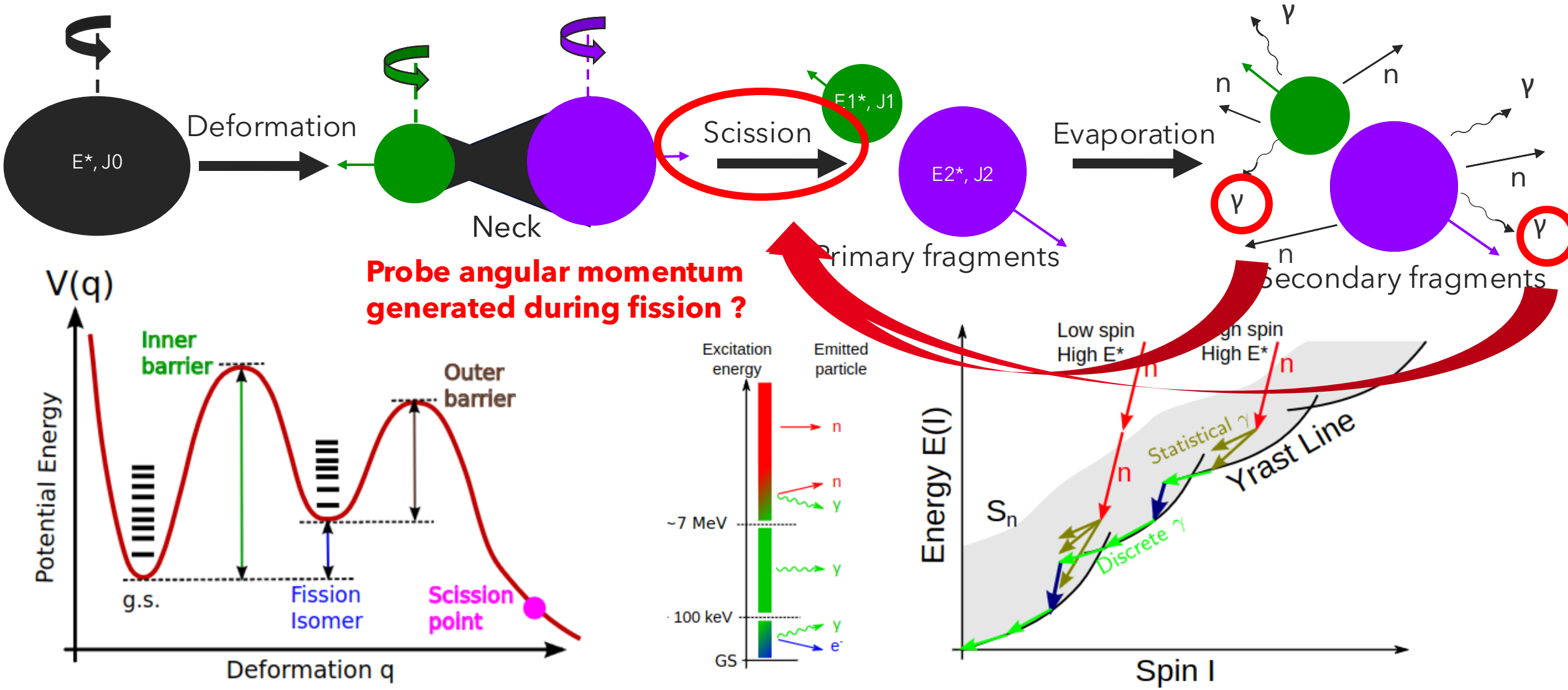

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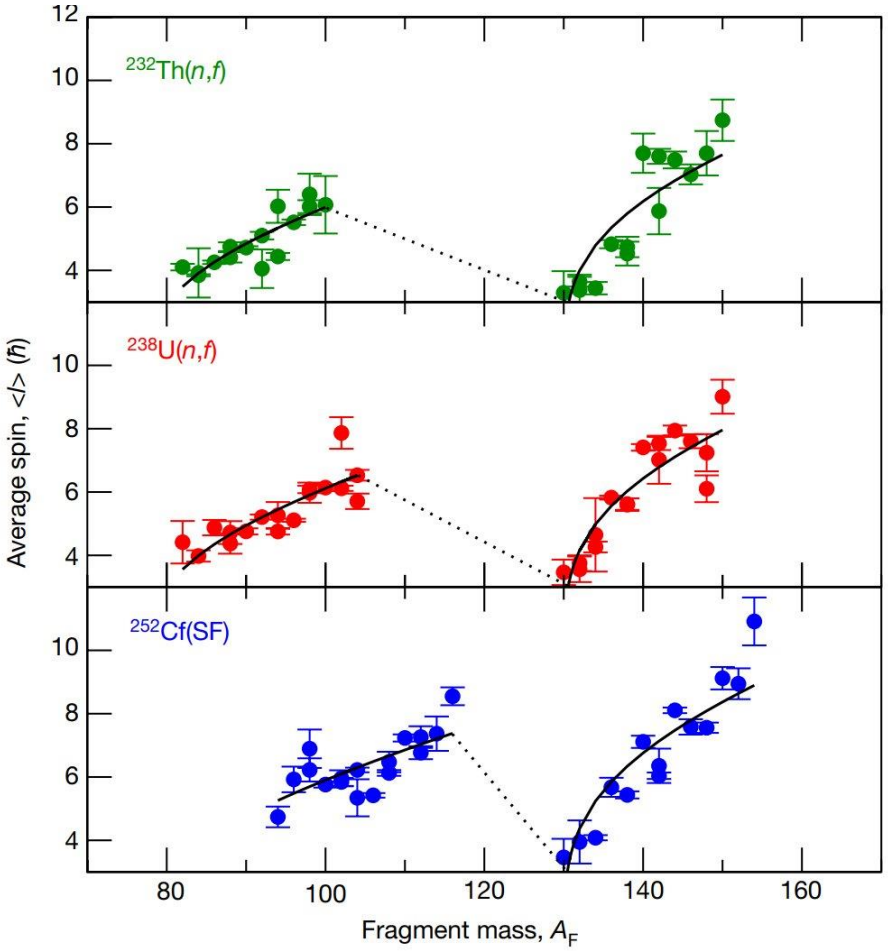
Previous experiments & theoretical developments



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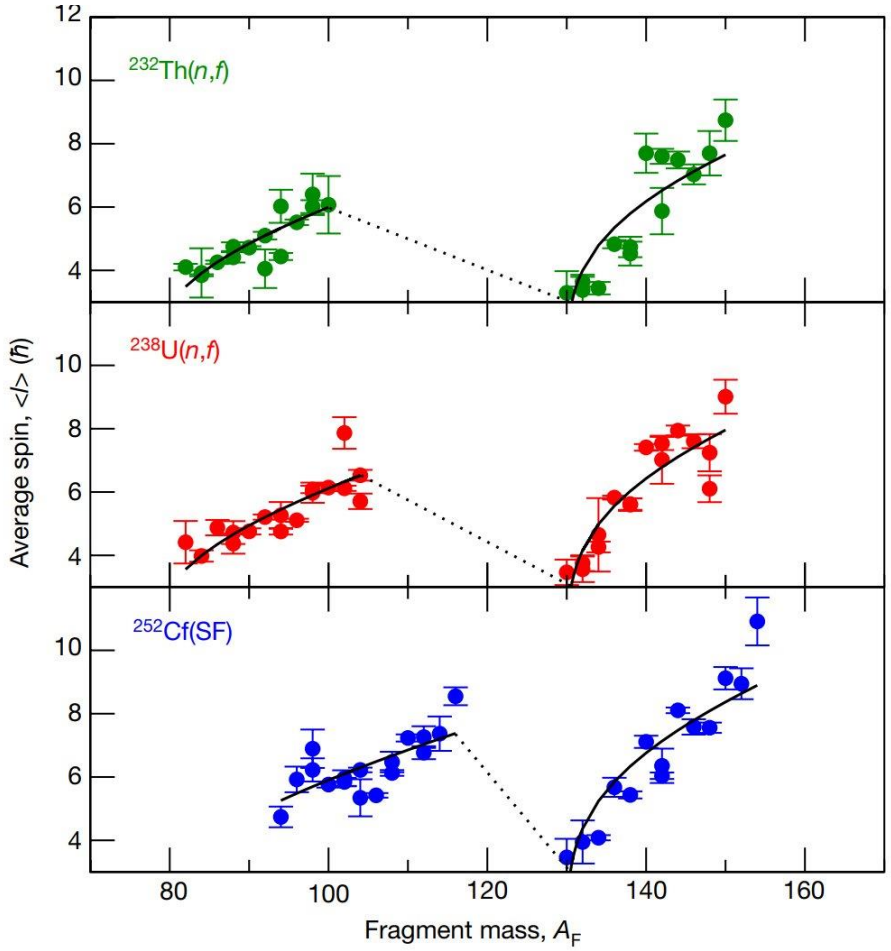

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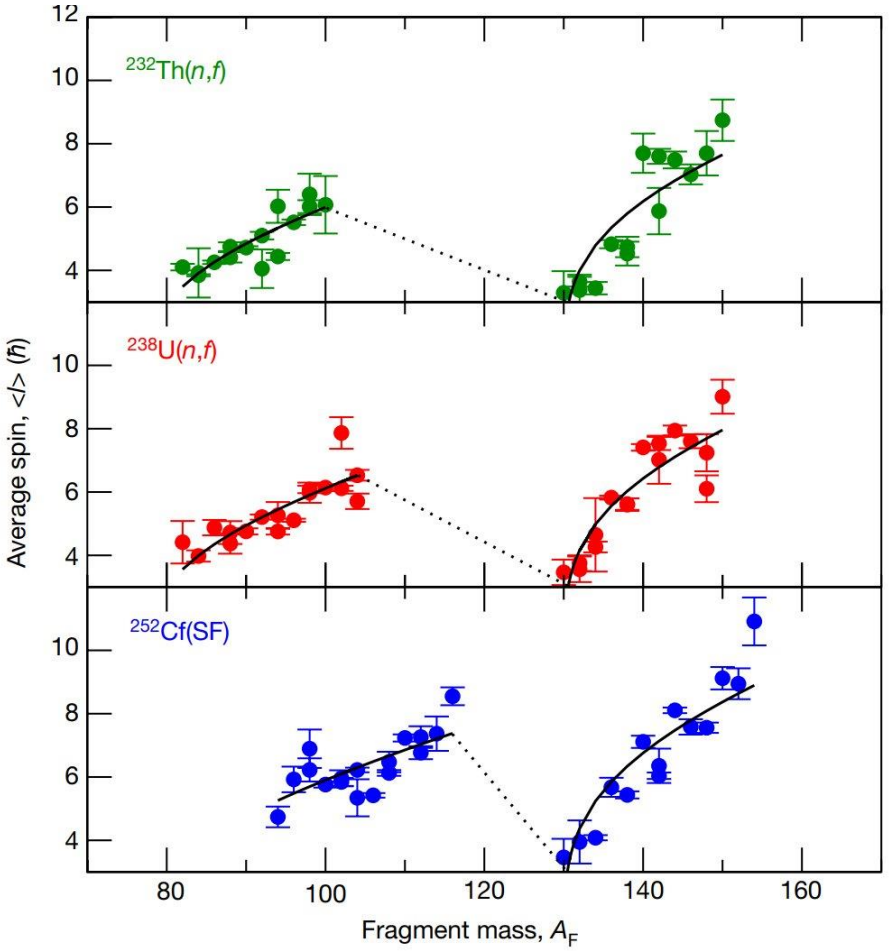

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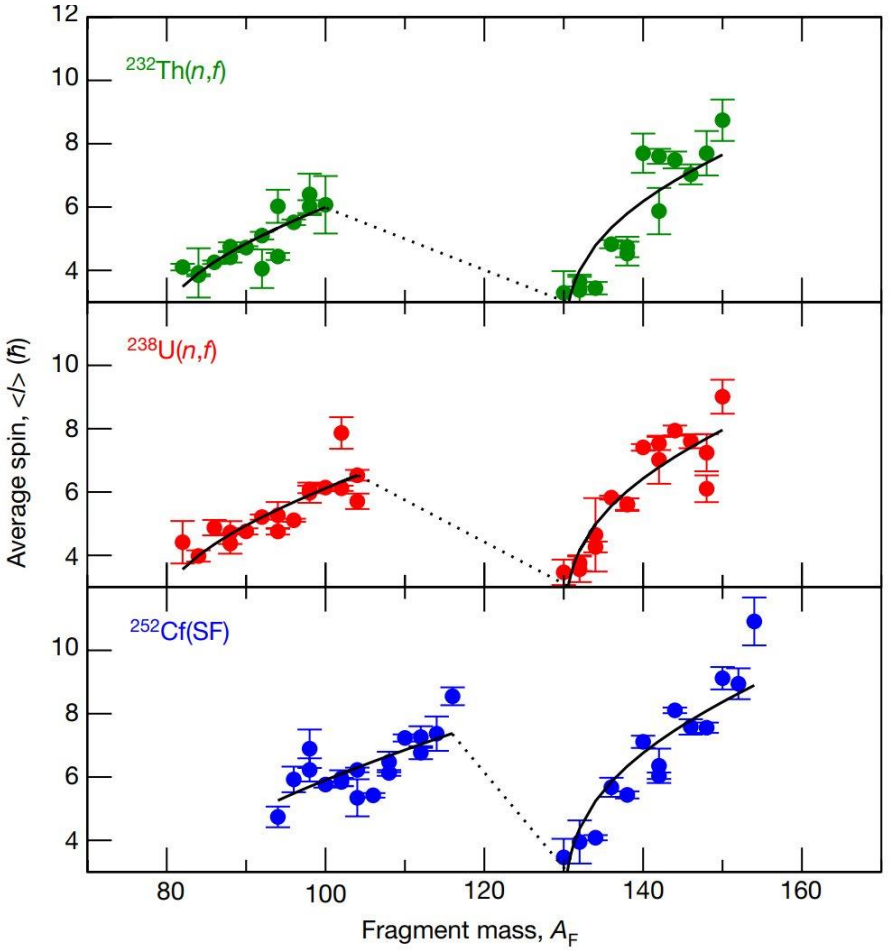

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Experiments:

- *J. N. Wilson et al. "Angular momentum generation in nuclear fission" . Nature 590.7847 (2021)* → **Low initial (E*,J)**
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Physics case: $^{238}U + ^{9}Be \rightarrow ^{247}Cm^{*}$

$^{247}CM^{*}$ initial conditions: $E^{*}_{CN} = 47$ MeV
Comparison with data from E826 (2022), $E^{*}_{CN}=43$ MeV

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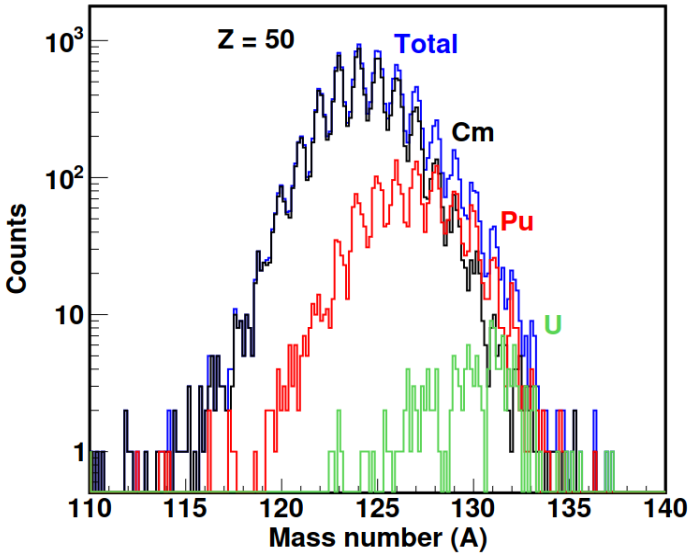

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→ Output channels are dominated by fusion-fission

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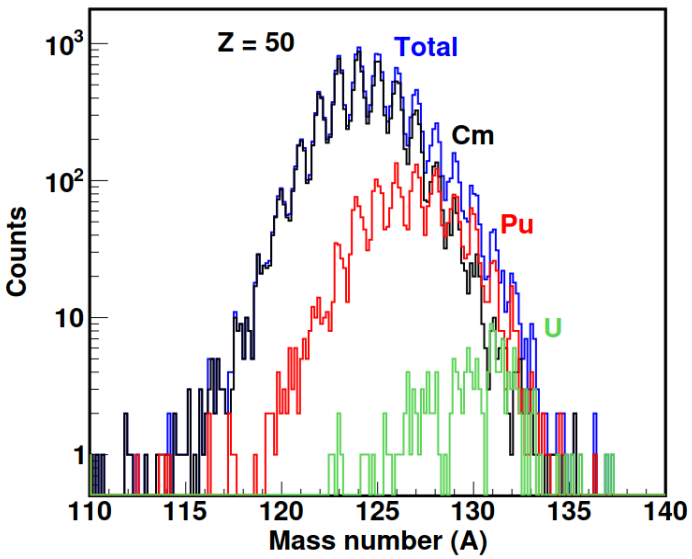

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Chance	Fissioning System	E_x (MeV)	Contribution (%)
1st chance [0n]	^{247}Cm	43	9.35
2nd chance [1n]	^{246}Cm	36	20.52
3rd chance [2n]	^{245}Cm	28	28.2
4th chance [3n]	^{244}Cm	20	31.6
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~ 2n evaporated in average before fission

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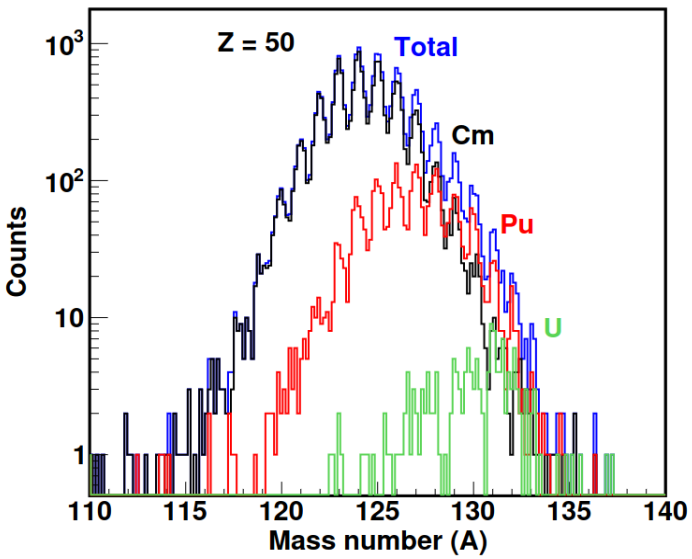

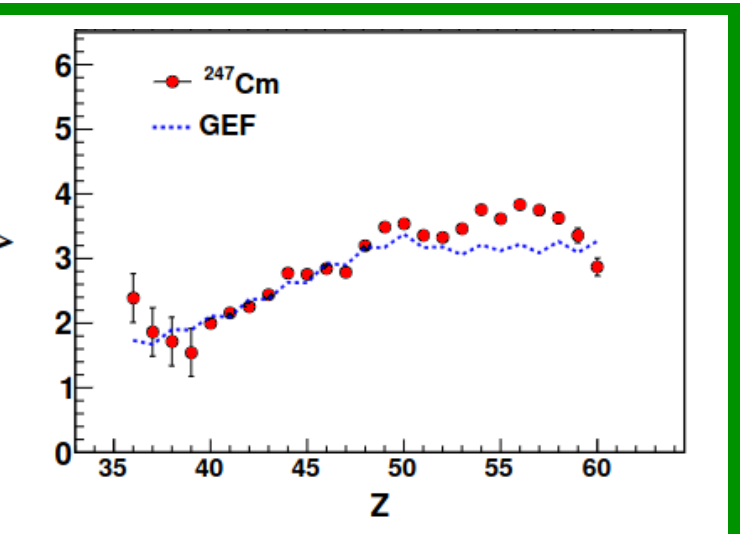

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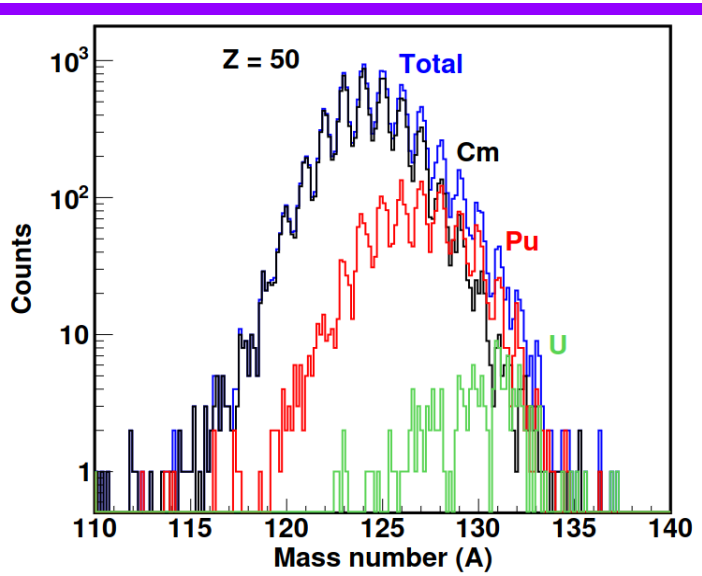

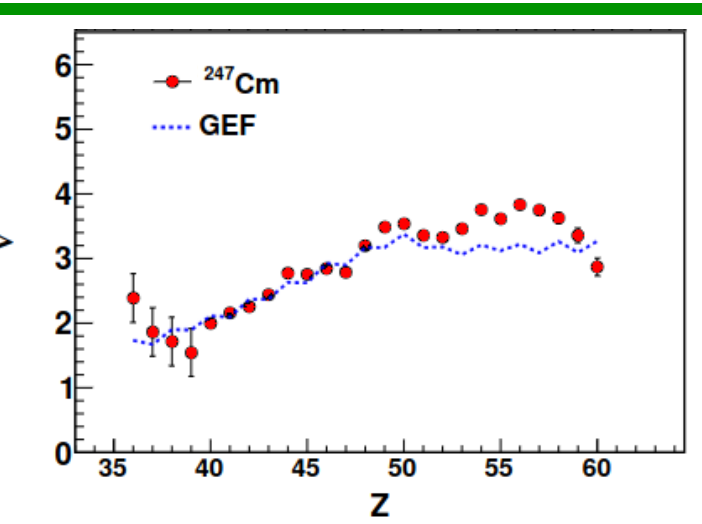

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Measure post neutron-evaporation masses

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Experiment E661: AGATA & VAMOS++

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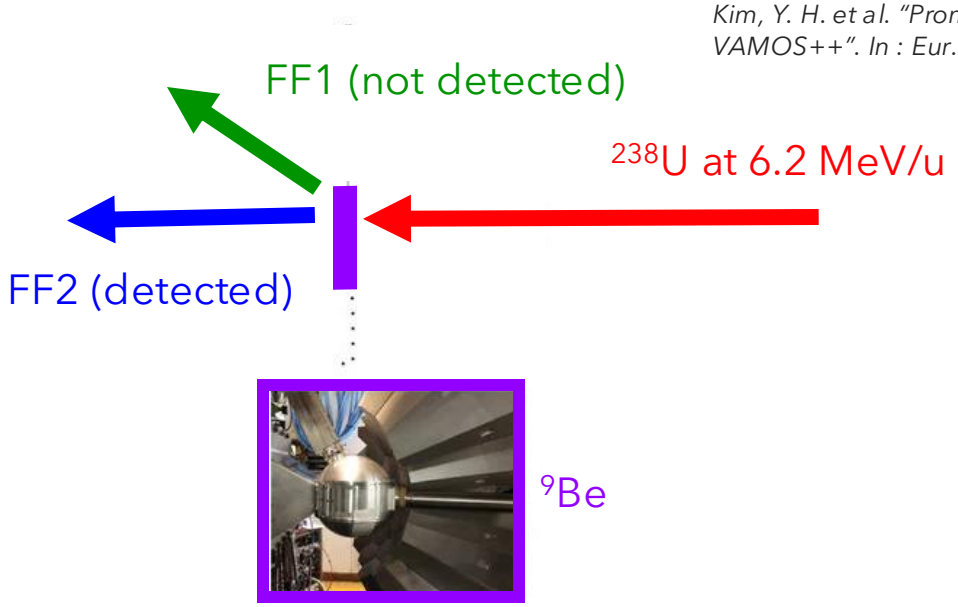

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ε_{AGATA} ~ 9.5 % at 1.2 MeV
Event by event doppler correction

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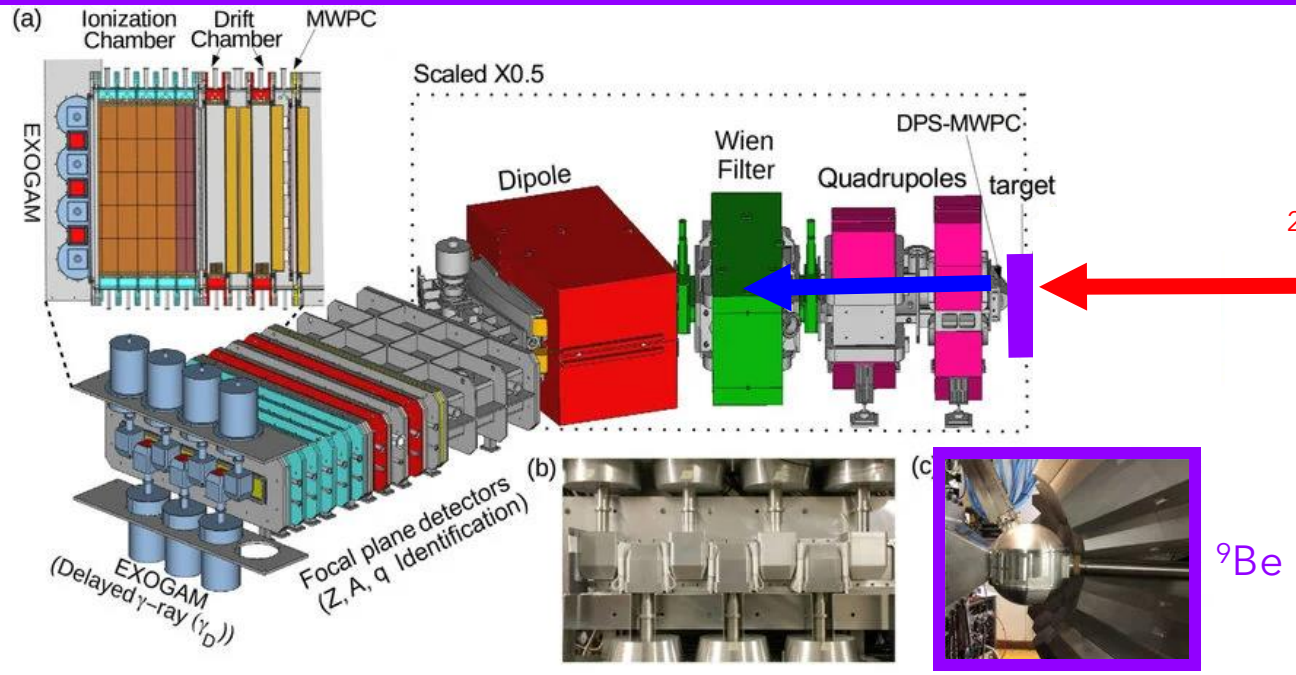

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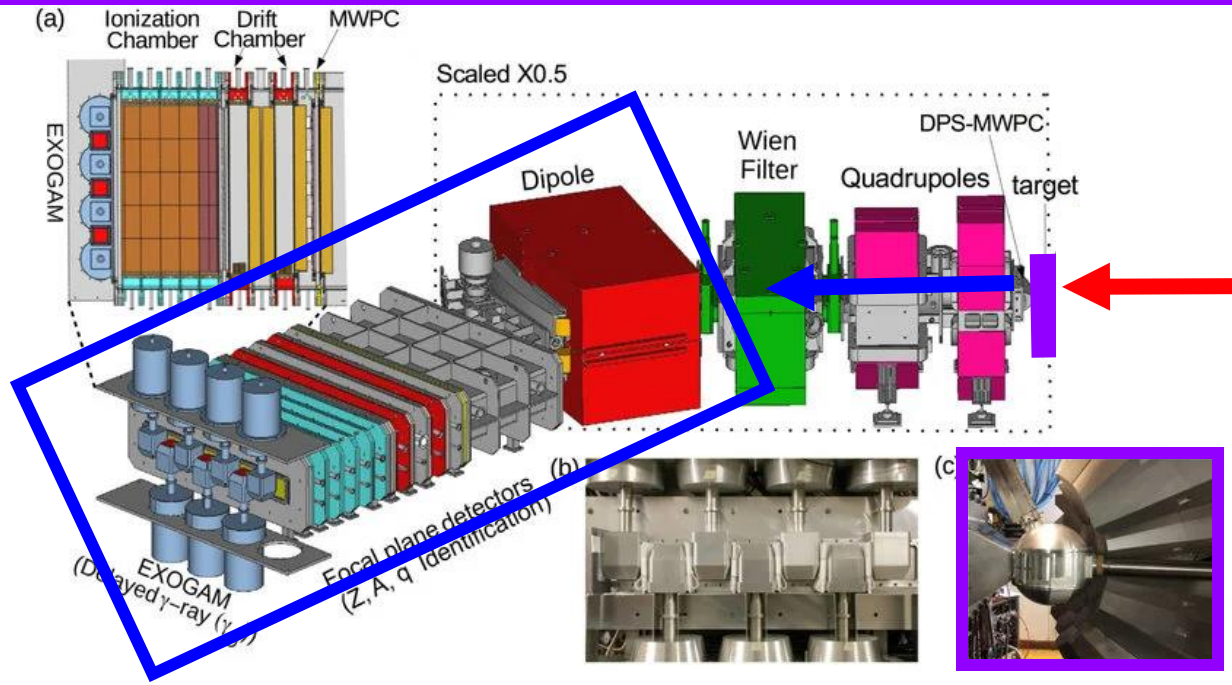

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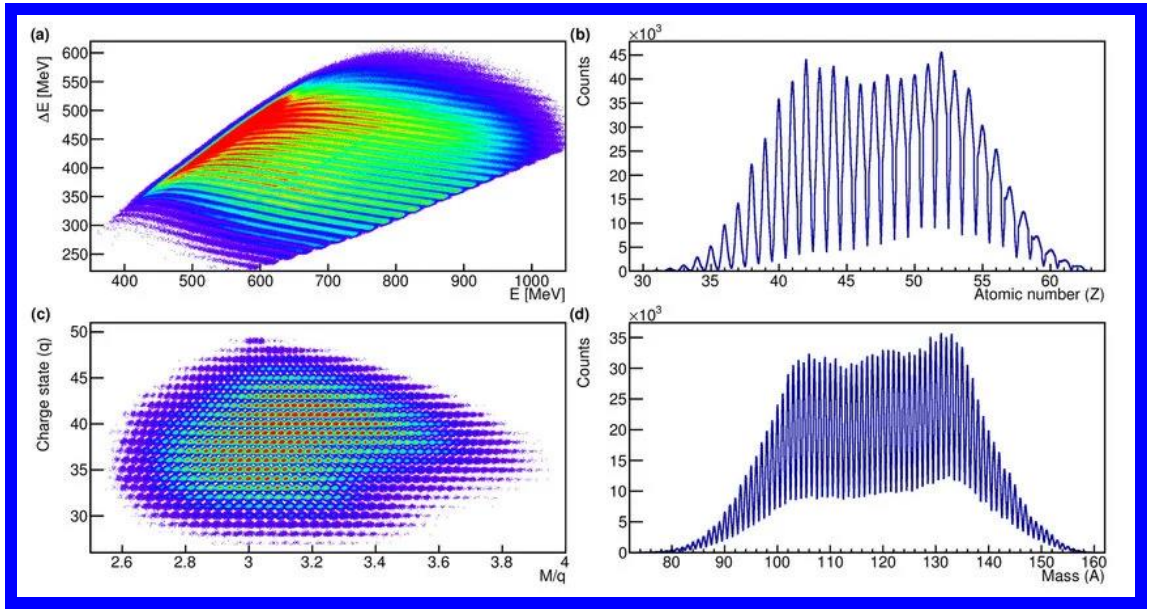

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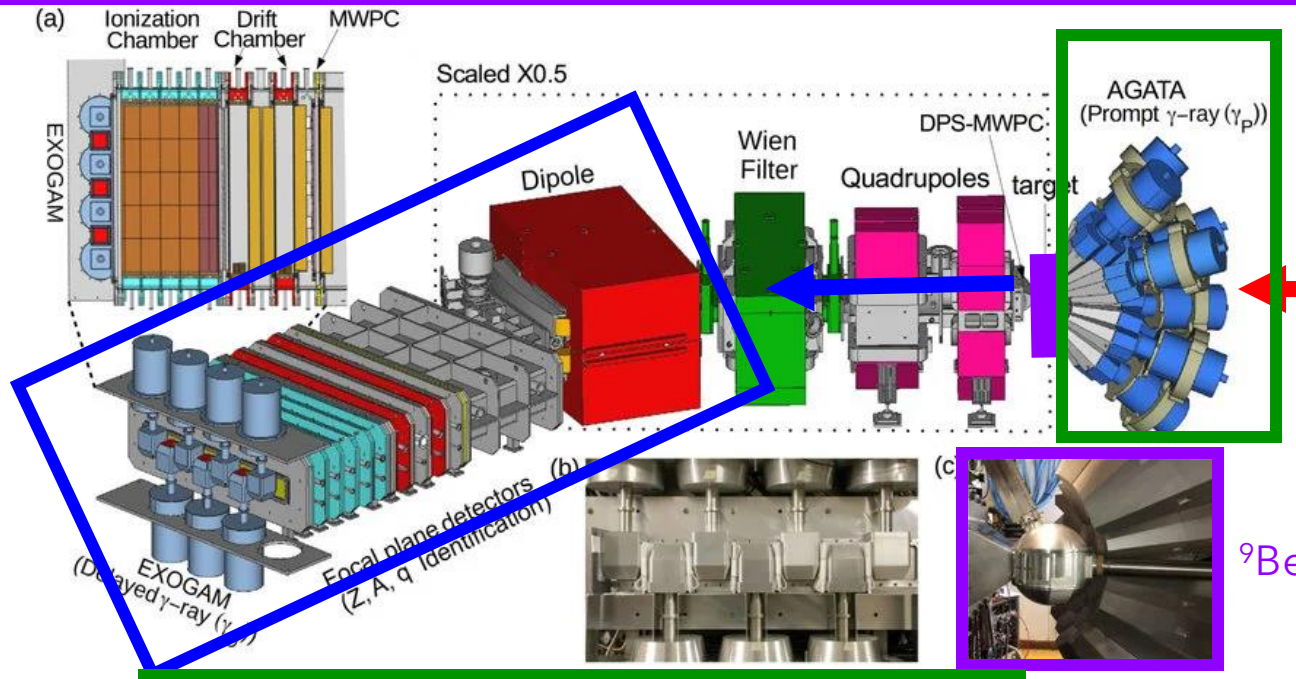

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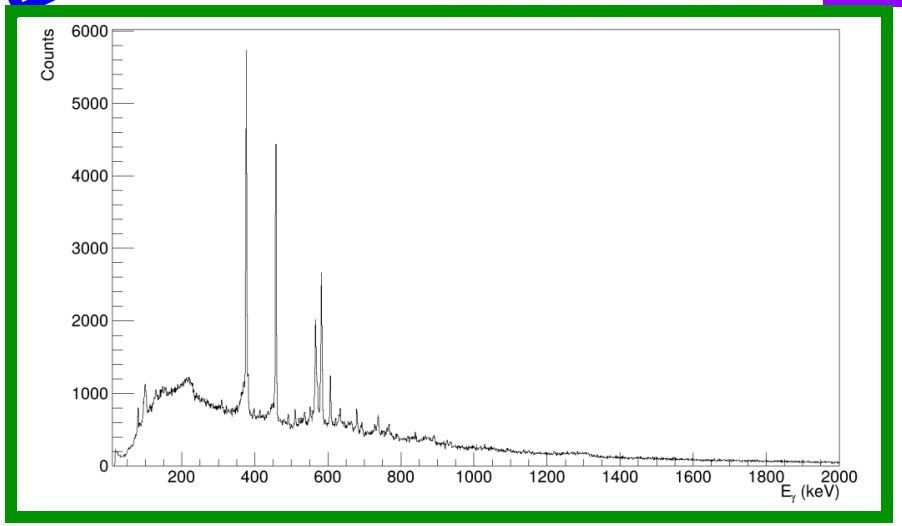
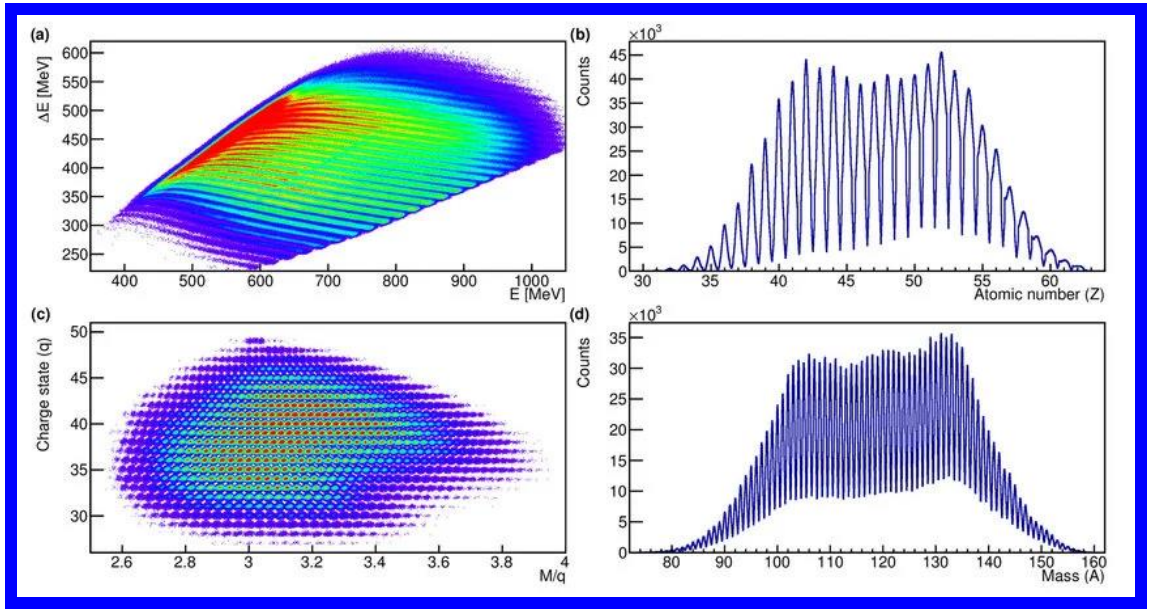


Promt γ-ray spectroscopy per isotope



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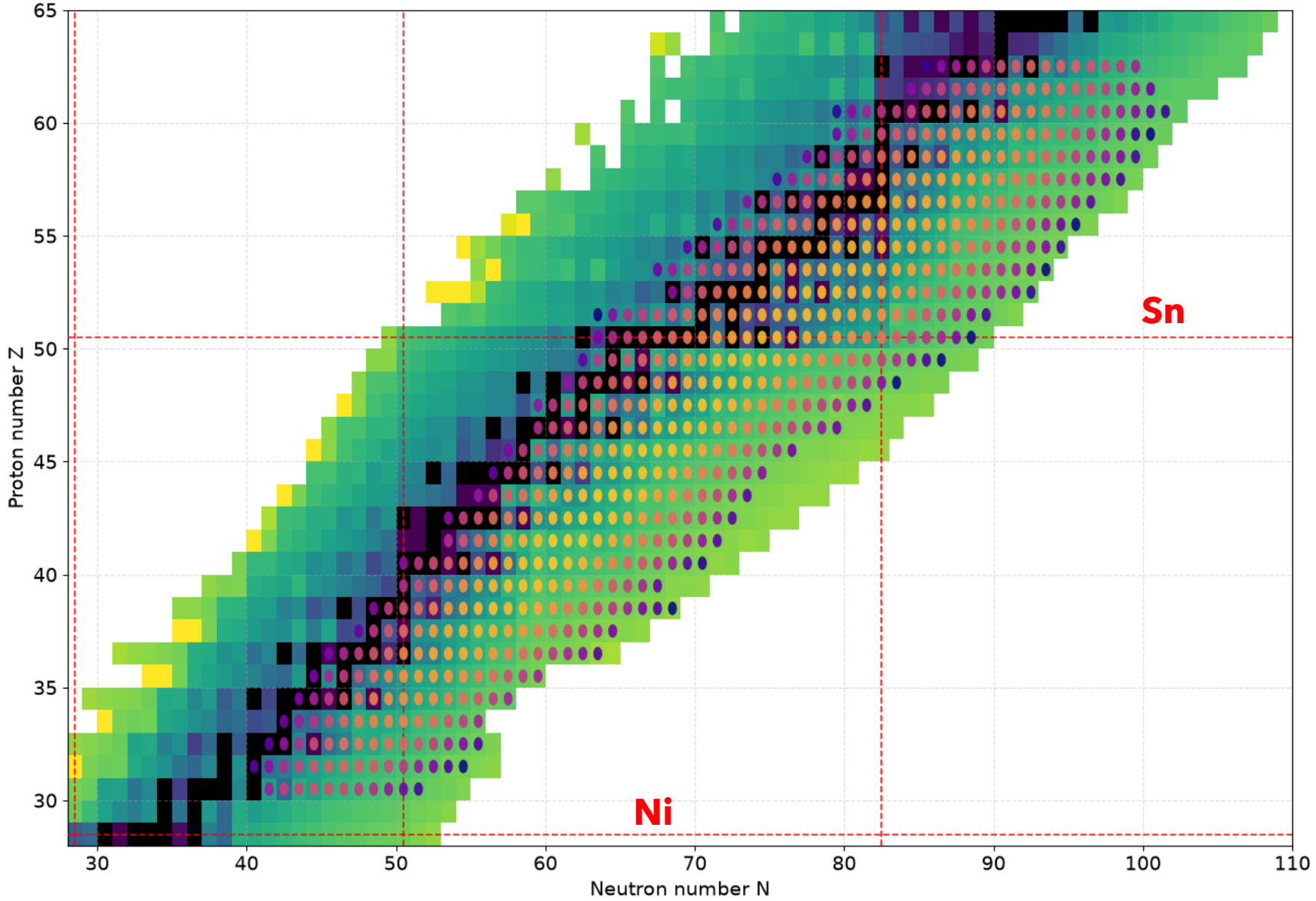
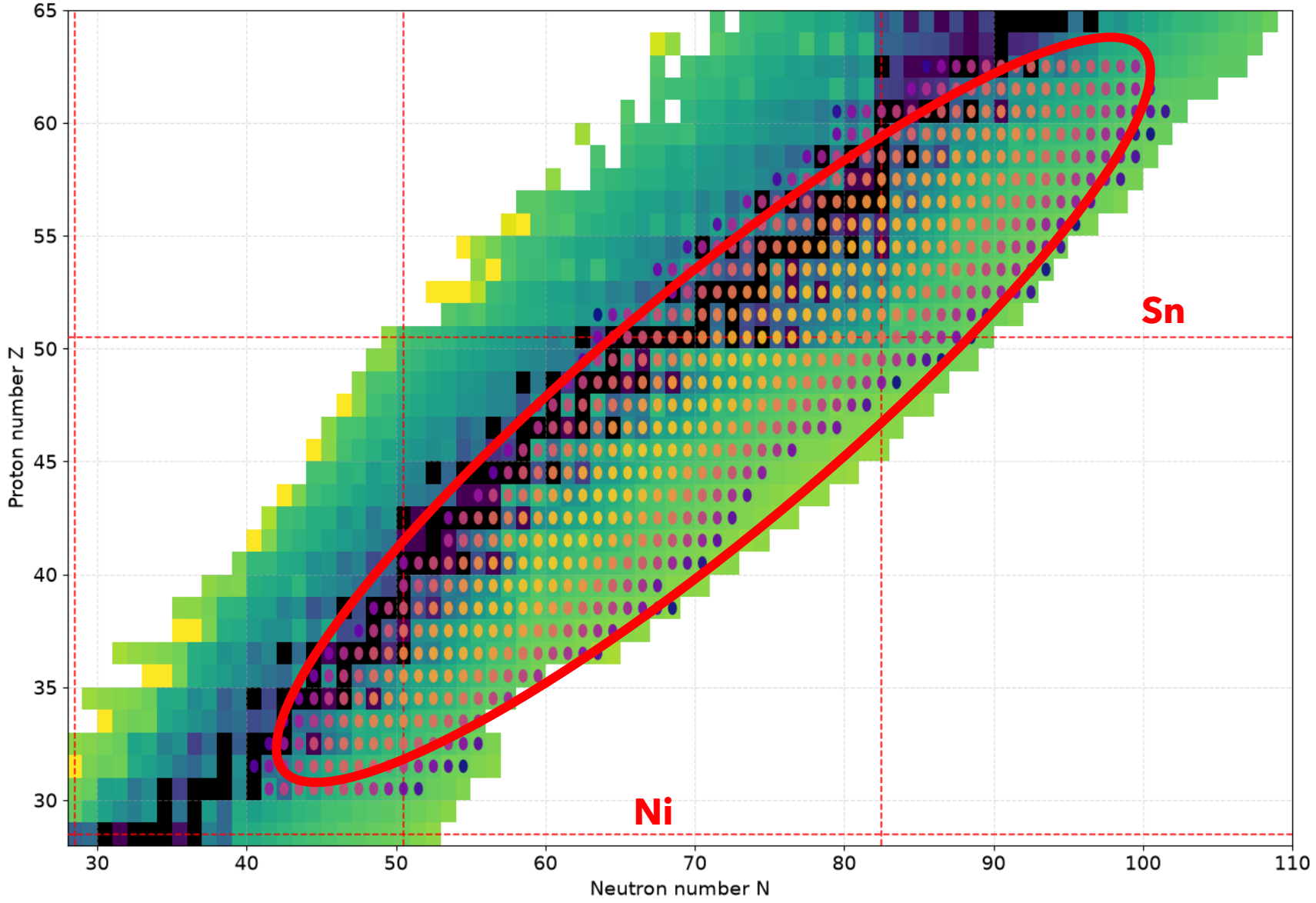
A wide range of isotopically identified isotopes



A wide range of isotopically identified isotopes

- $Z \in [\,30, 62\,]$
- $N \in [\,40, 101\,]$
- $A \in [\,71, 161\,]$



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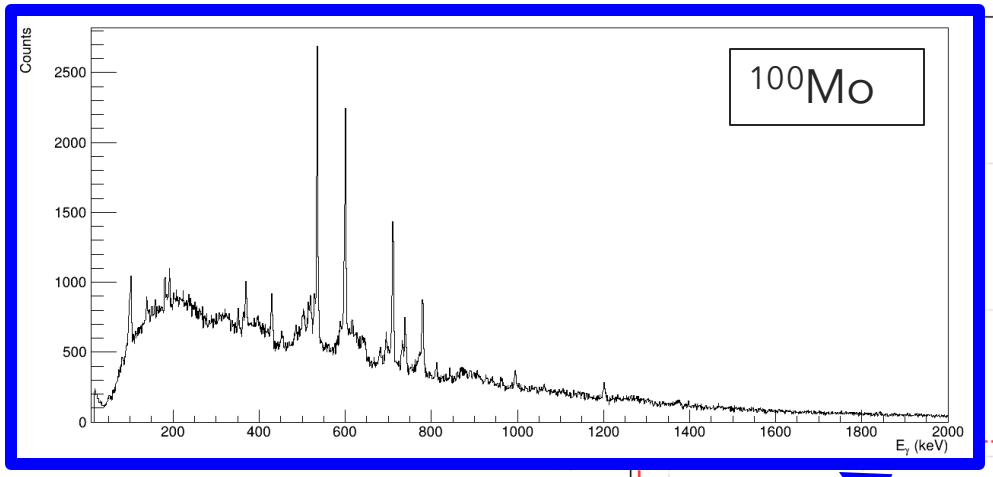
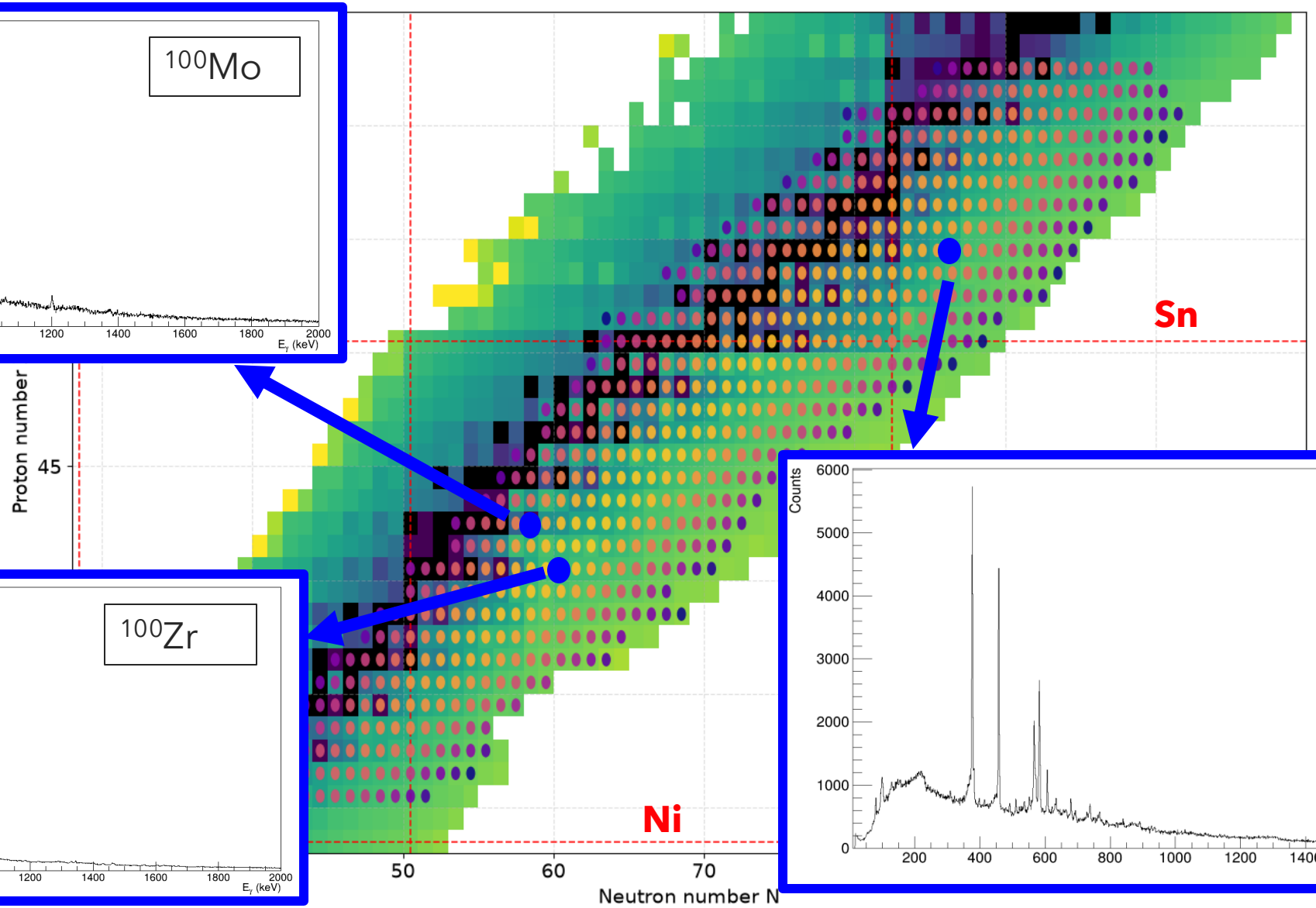
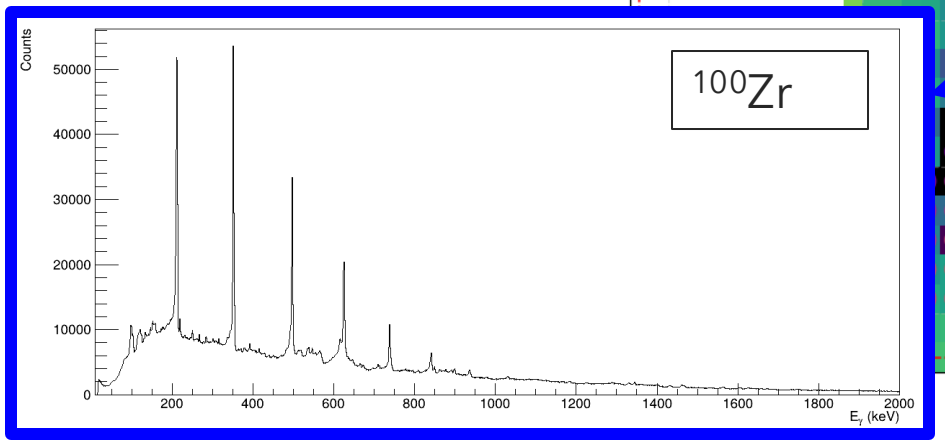
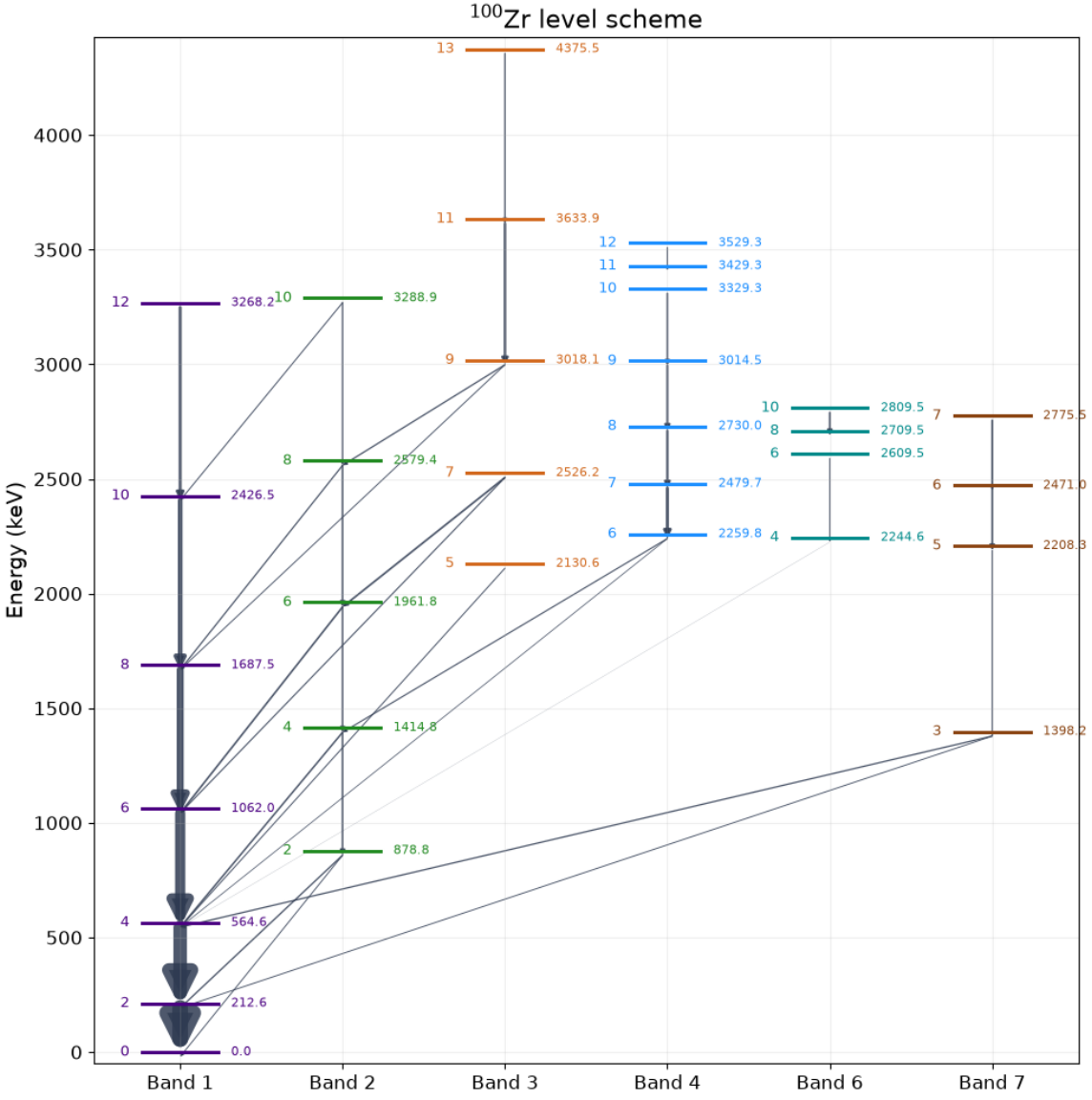






From γ-ray spectra to spin distributions



- Extract intensities for every statistically relevant peak
- Check branching ratios self-consistency and with available data

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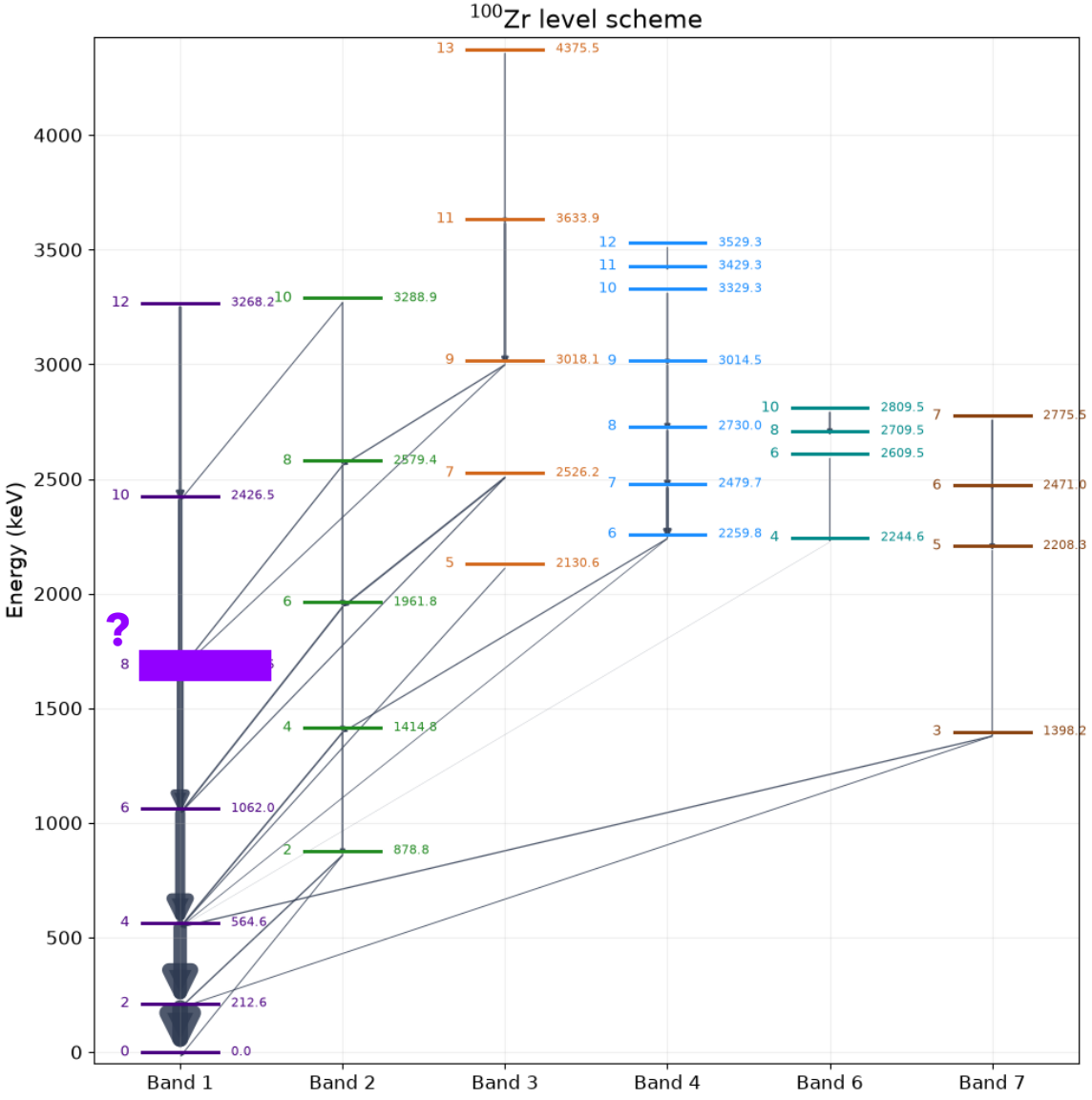

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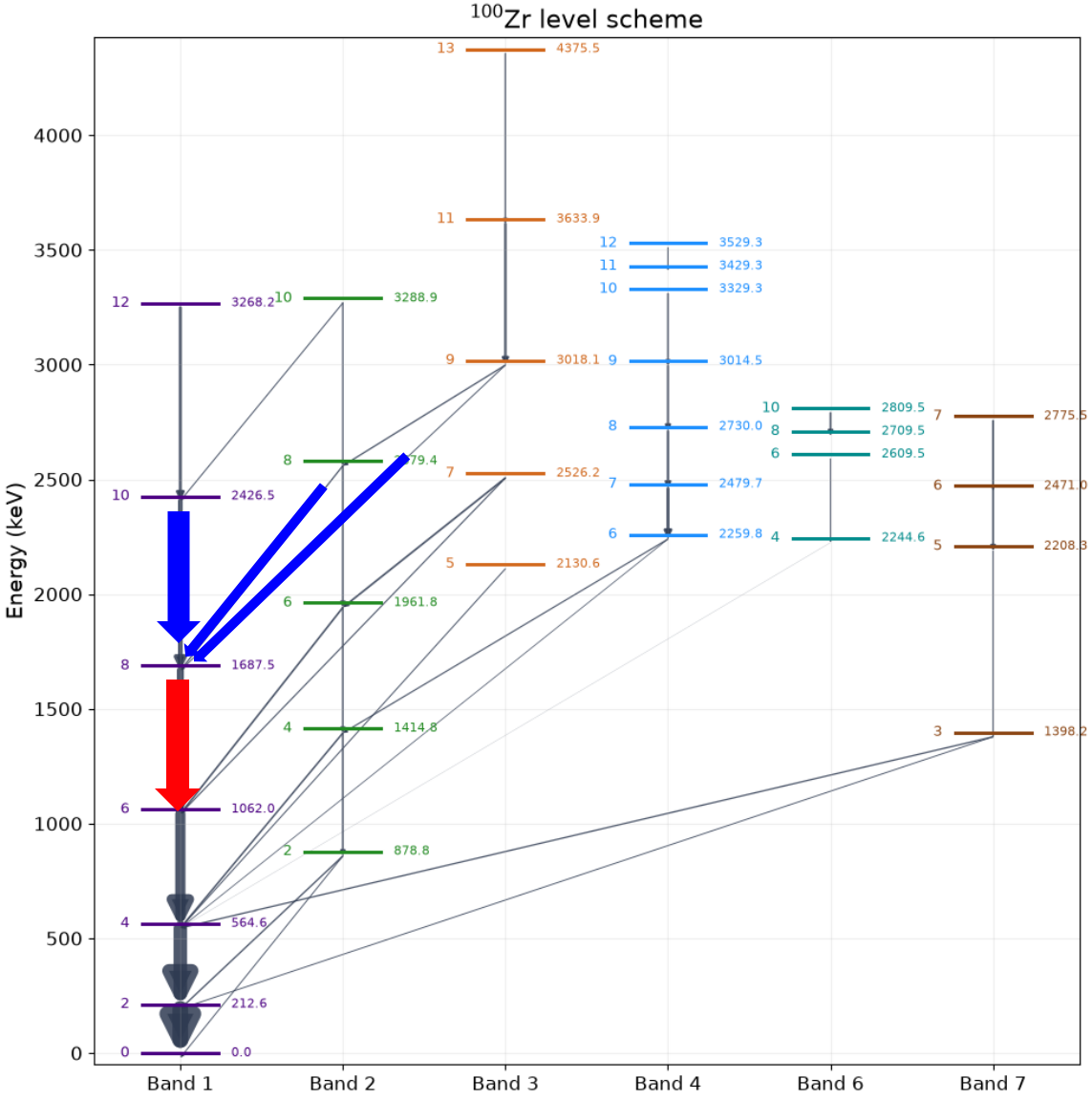
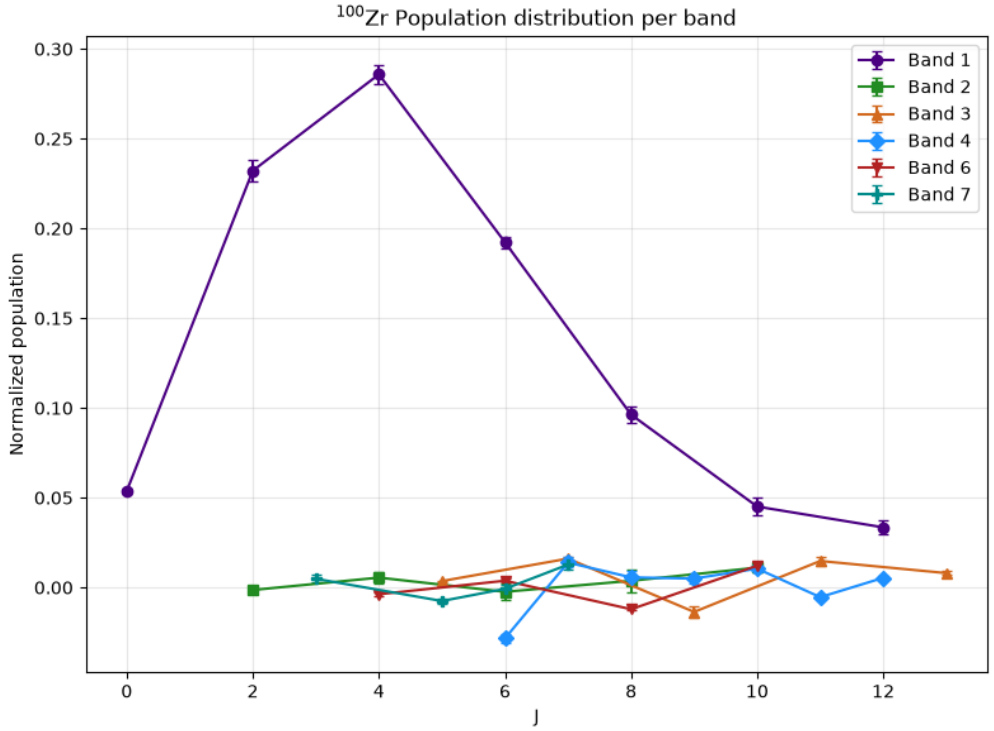


OUT - IN



- Extract intensities for every statistically relevant peak
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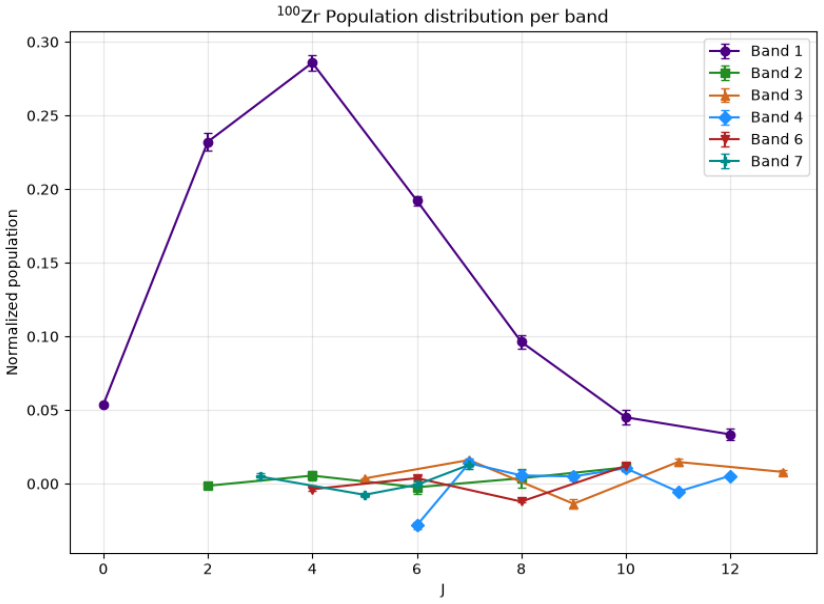
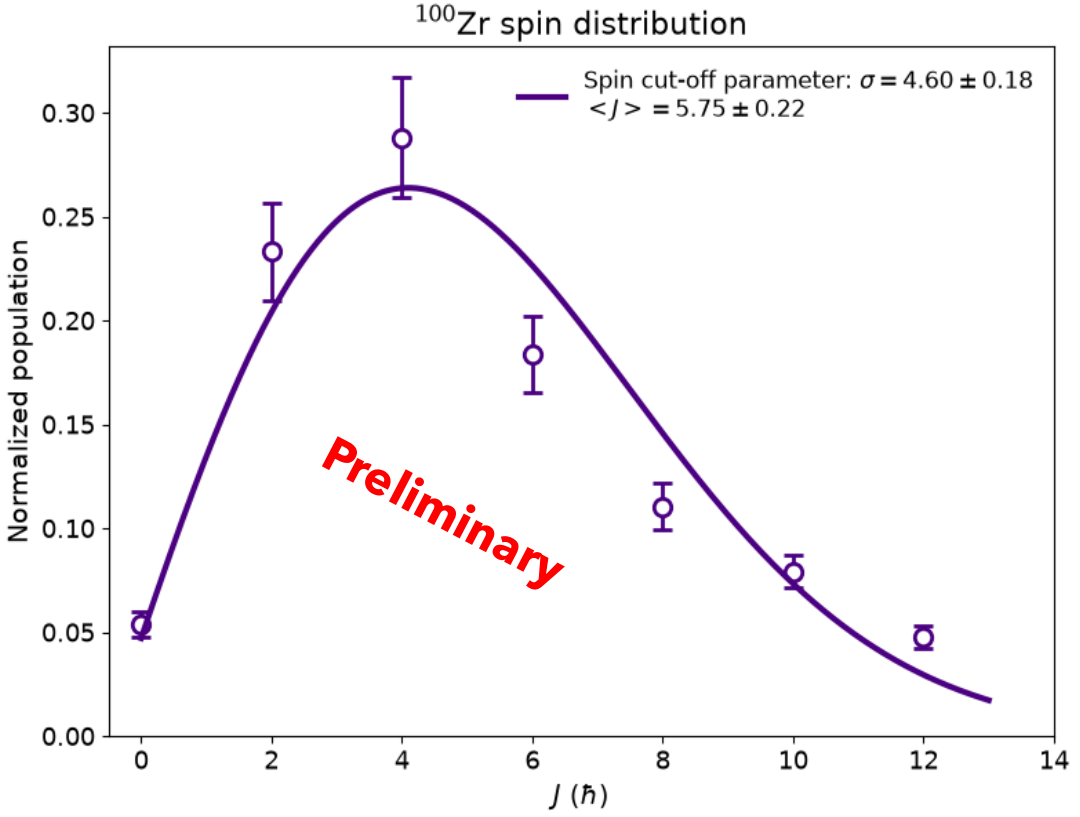
- Population for a level = gamma-rays out – gamma-rays in (correct for efficiency and internal conversion)
- Check consistency in the population distribution

From γ-ray spectra to spin distributions



- Sum over populations for each J
- Spread Odd populations equally between their neighbors
- Extract the J=0 population & renormalize (iteratively)
- Extract **<I> = 1.25 σ**

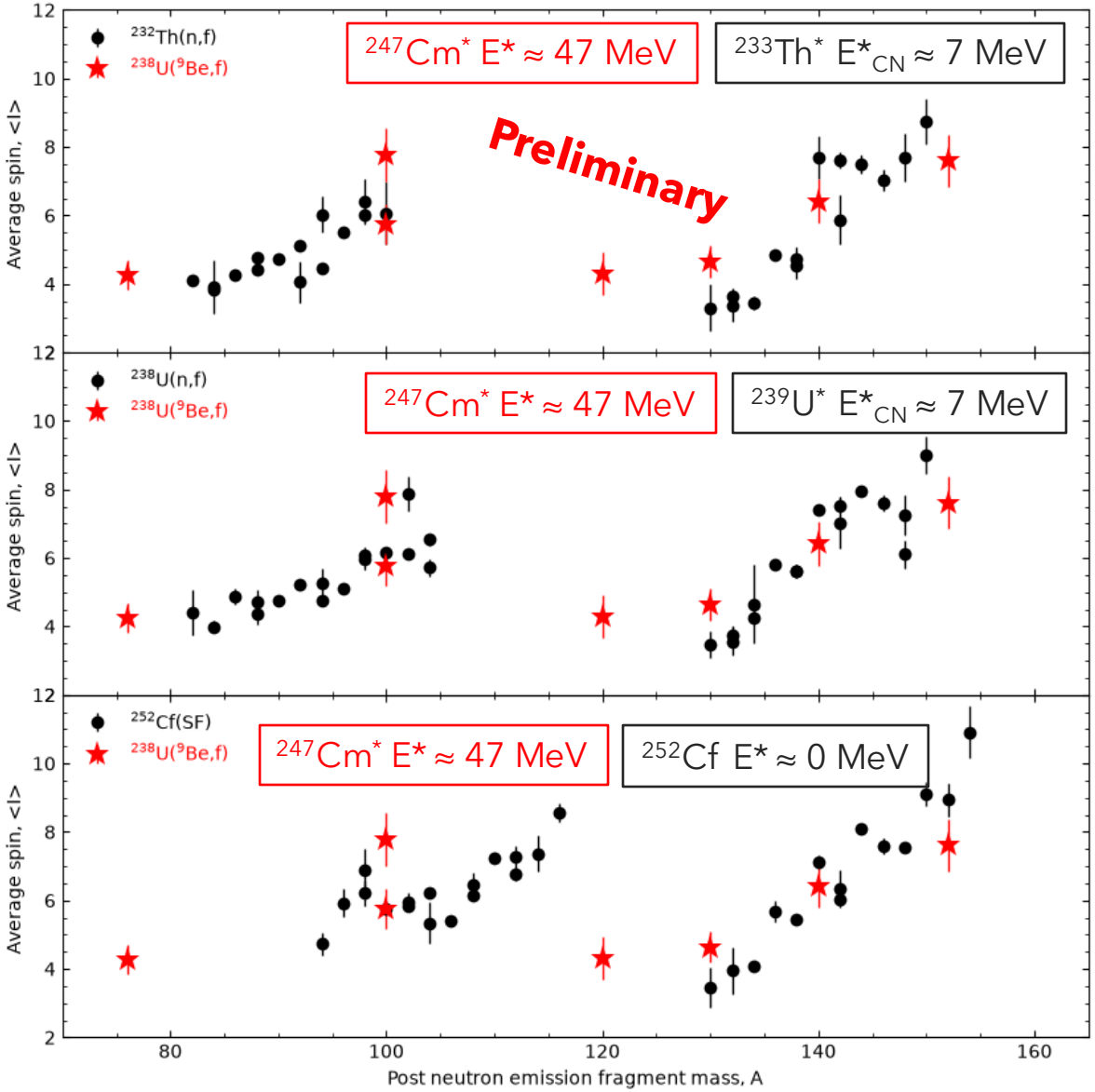


Rayleigh distribution:

$$P(J) = \frac{2J+1}{2\sigma^2} \exp\left[-\frac{(J+\frac{1}{2})^2}{2\sigma^2}\right]$$

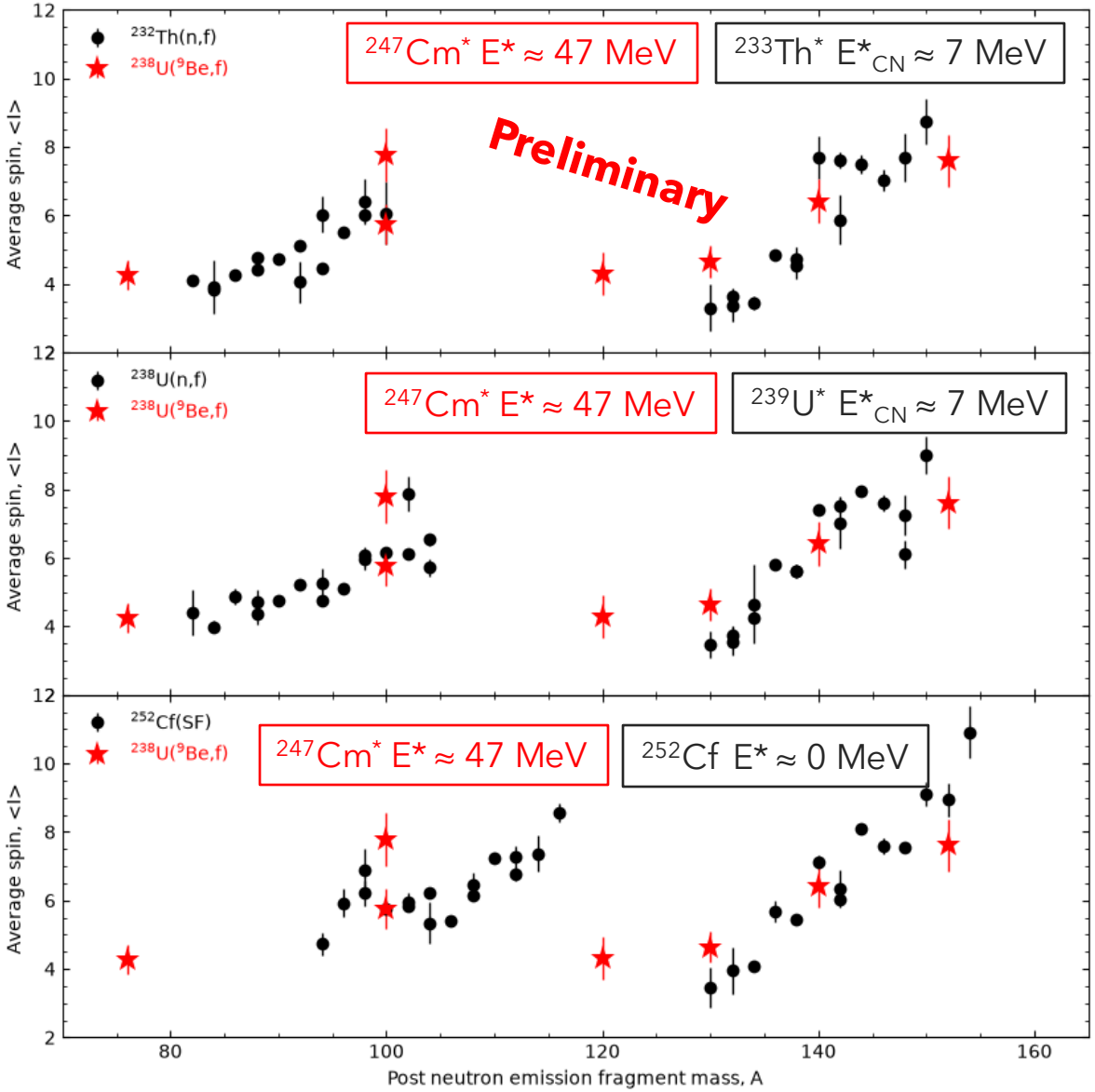
NB: Same procedure as Wilson

Comparison with SF/n-induced fission



J. N. Wilson et al. "Angular momentum generation in nuclear fission." . In : Nature 590.7847 (fév. 2021)

Comparison with SF/n-induced fission



Observations:

- Different entrance channel but same trend

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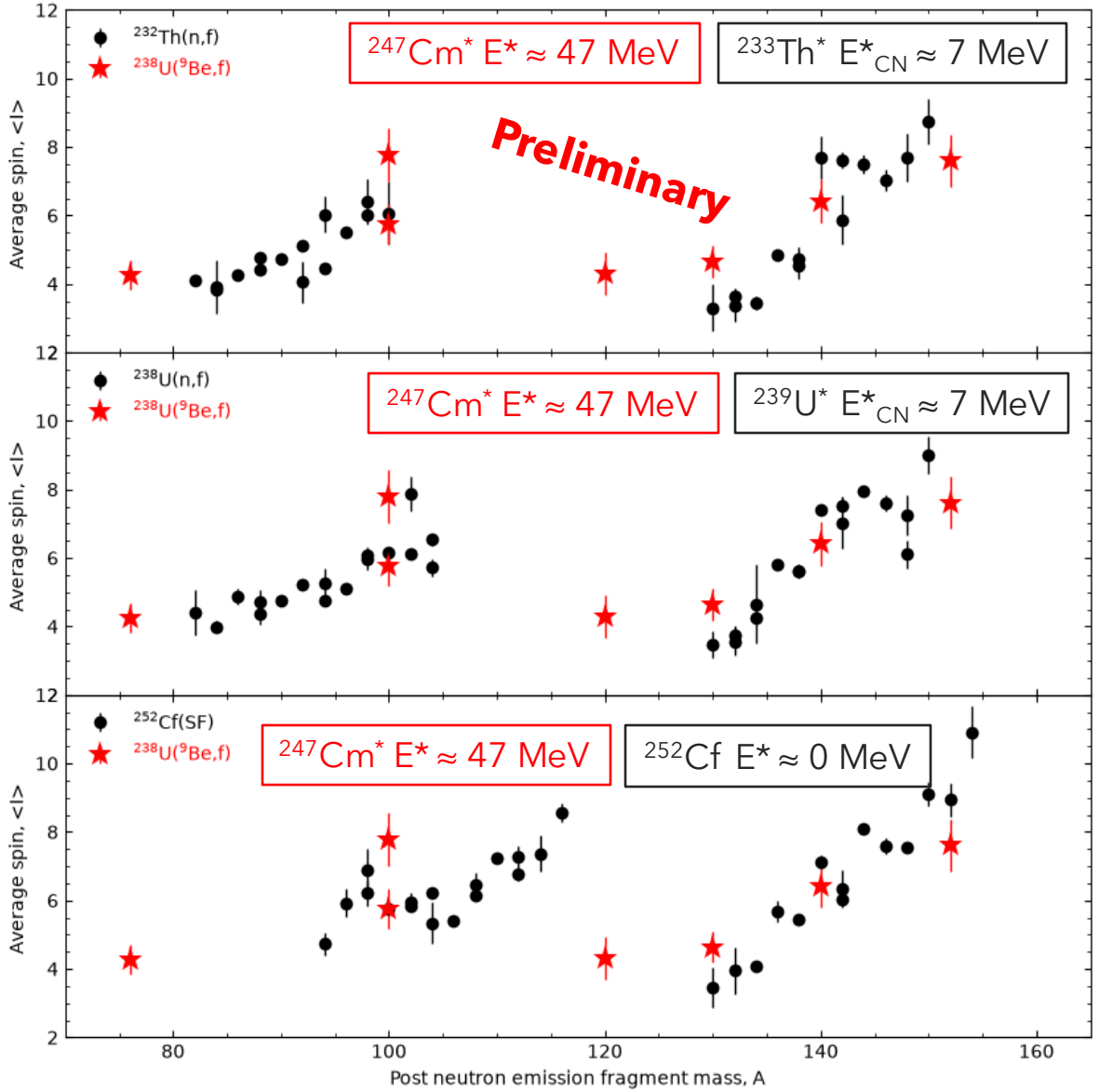
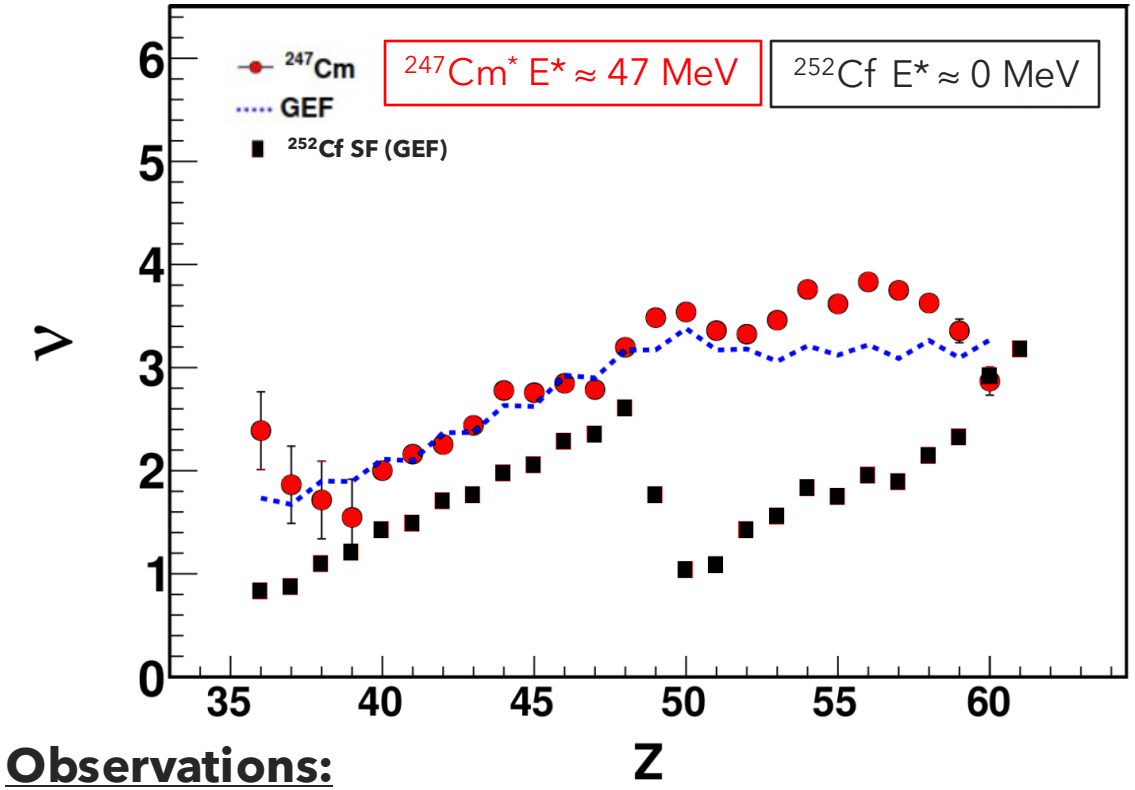
Comparison with SF/n-induced fission



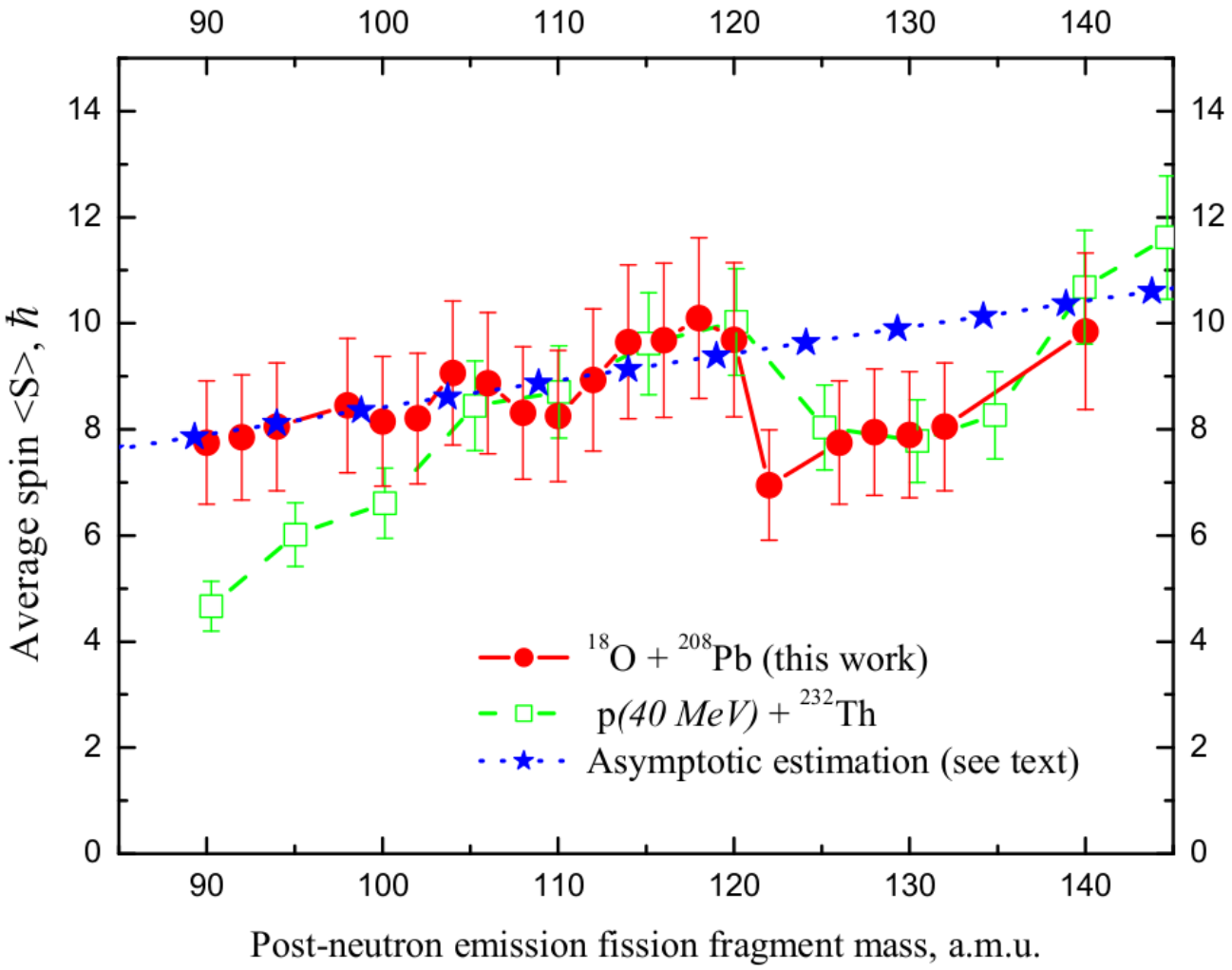


Observations:

- Different entrance channel but same trend
- Evolution of sawtooth pattern in ν not reproduced in <J>
- Limited influence of the entrance channel on <J> ?

J. N. Wilson et al. "Angular momentum generation in nuclear fission." . In : Nature 590.7847 (fév. 2021)

Comparison with another fusion-fission dataset



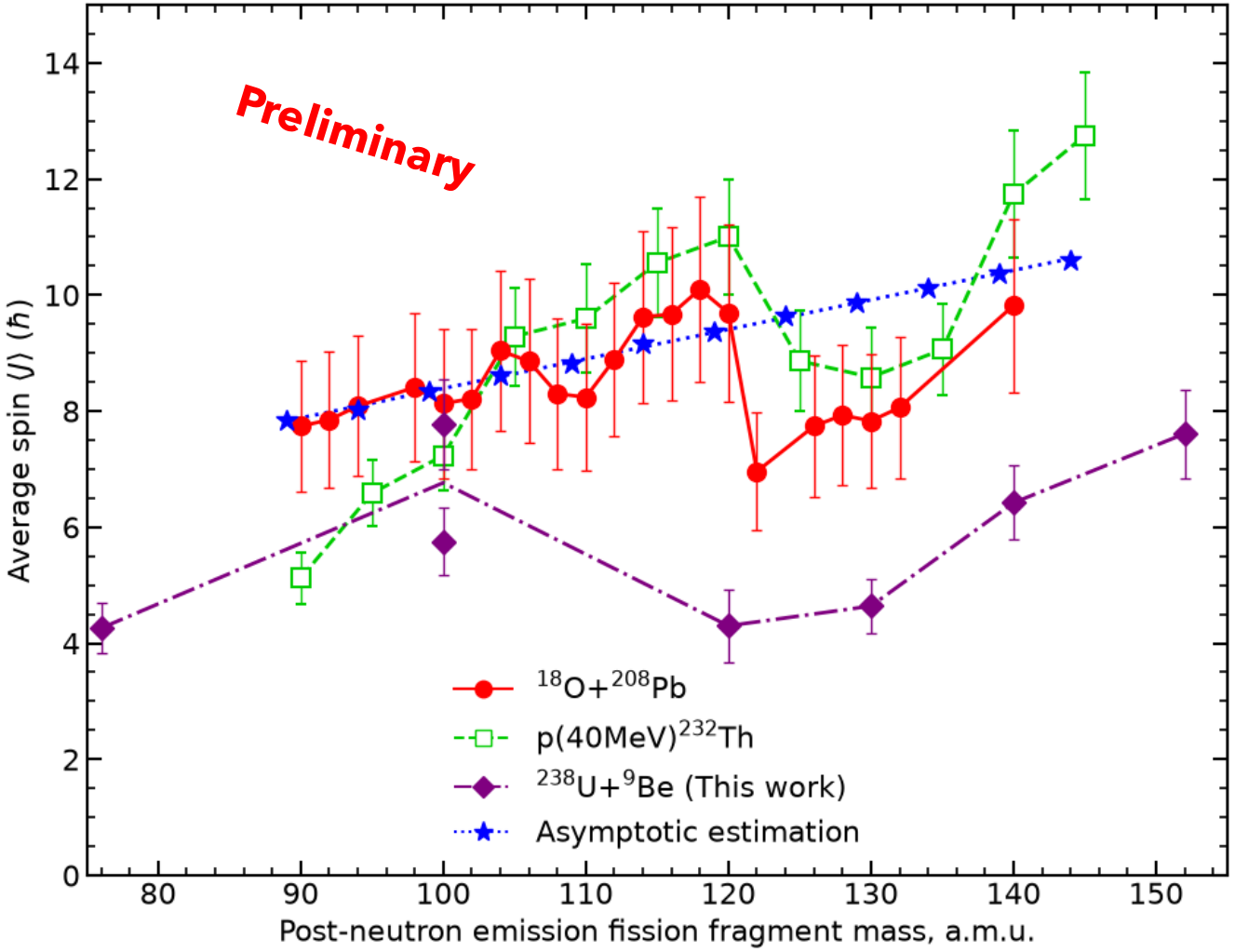
A. Bogachev et al. "Fission fragment properties obtained in the γ-γ-γ coincidence method in the reaction $^{208}Pb(^{18}O, f)$". Eur. Phys. J. A 34 (2007)

$^{226}Th^{*}$ E* ≈ 34 MeV

$^{233}Pa^{*}$ E* ≈ 44 MeV

- Data extracted using triple γ-ray coïncidences with EUROBALL
- Sawtooth pattern also observed here
- Slightly different spin extraction procedure

Comparison with another fusion-fission dataset



A. Bogachev et al. "Fission fragment properties obtained in the γ-γ-γ coincidence method in the reaction $^{208}Pb(^{18}O, f)$". Eur. Phys. J. A 34 (2007)

$^{226}Th^{*}$ E* ≈ 34 MeV

$^{233}Pa^{*}$ E* ≈ 44 MeV

$^{247}Cm^{*}$ E* ≈ 47 MeV

- Data extracted using triple γ-ray coïncidences with EUROBALL
- Sawtooth pattern also observed here
- Slightly different spin extraction procedure
- Systematically lower <J> in our case: method or physics?
- To be studied next

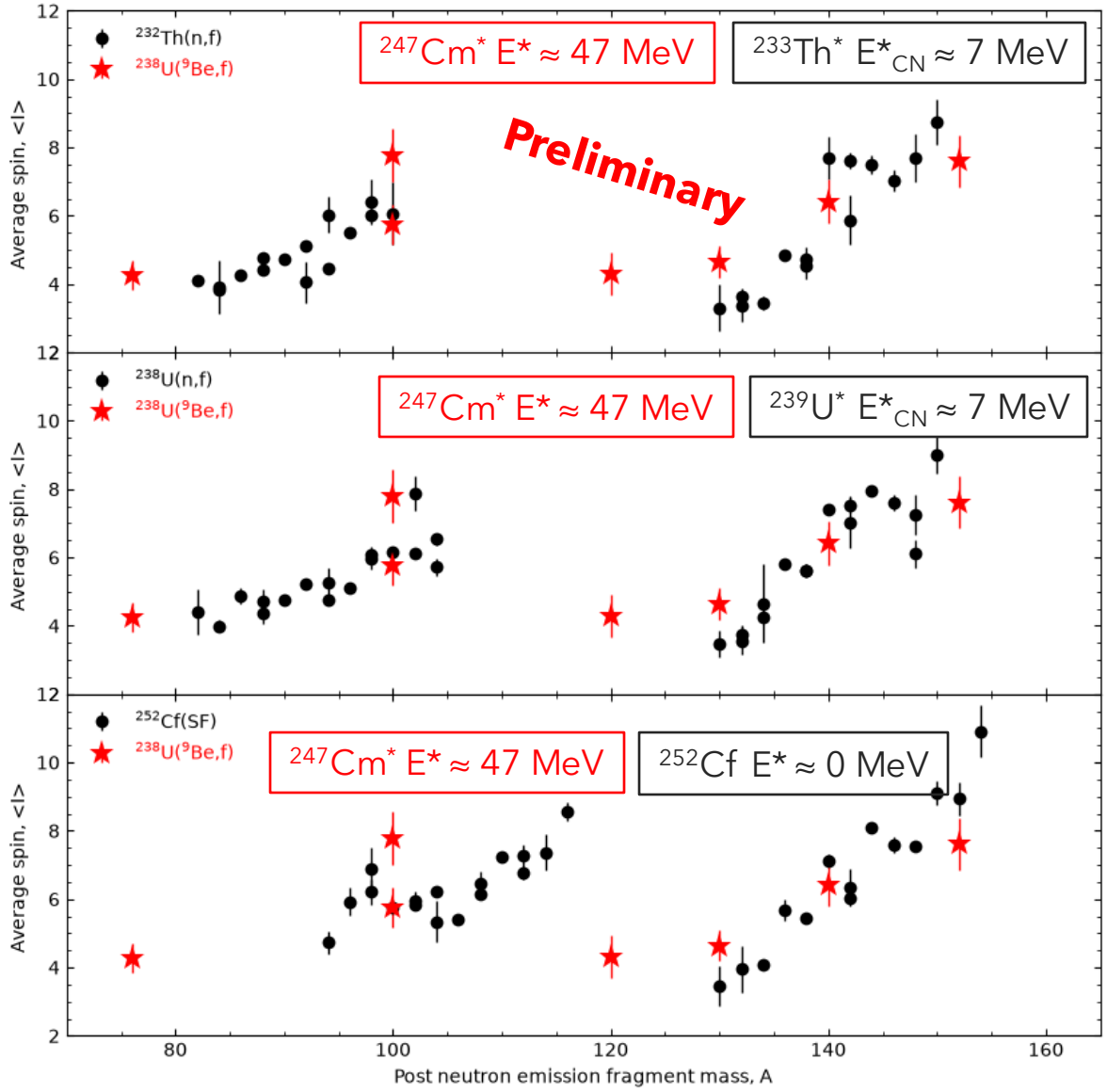
Conclusion & Outlooks

Summary:

- Experiment at AGATA & VAMOS++ to probe high (E*,J) fission of ^{247}Cm* through γ-ray spectroscopy
- Data from E661 (2016) re-analyzed for this physics case
- Similar trend for <J>= f(A) as in SF/n-induced fision
- Limited influence of the entrance channel on <J> ?

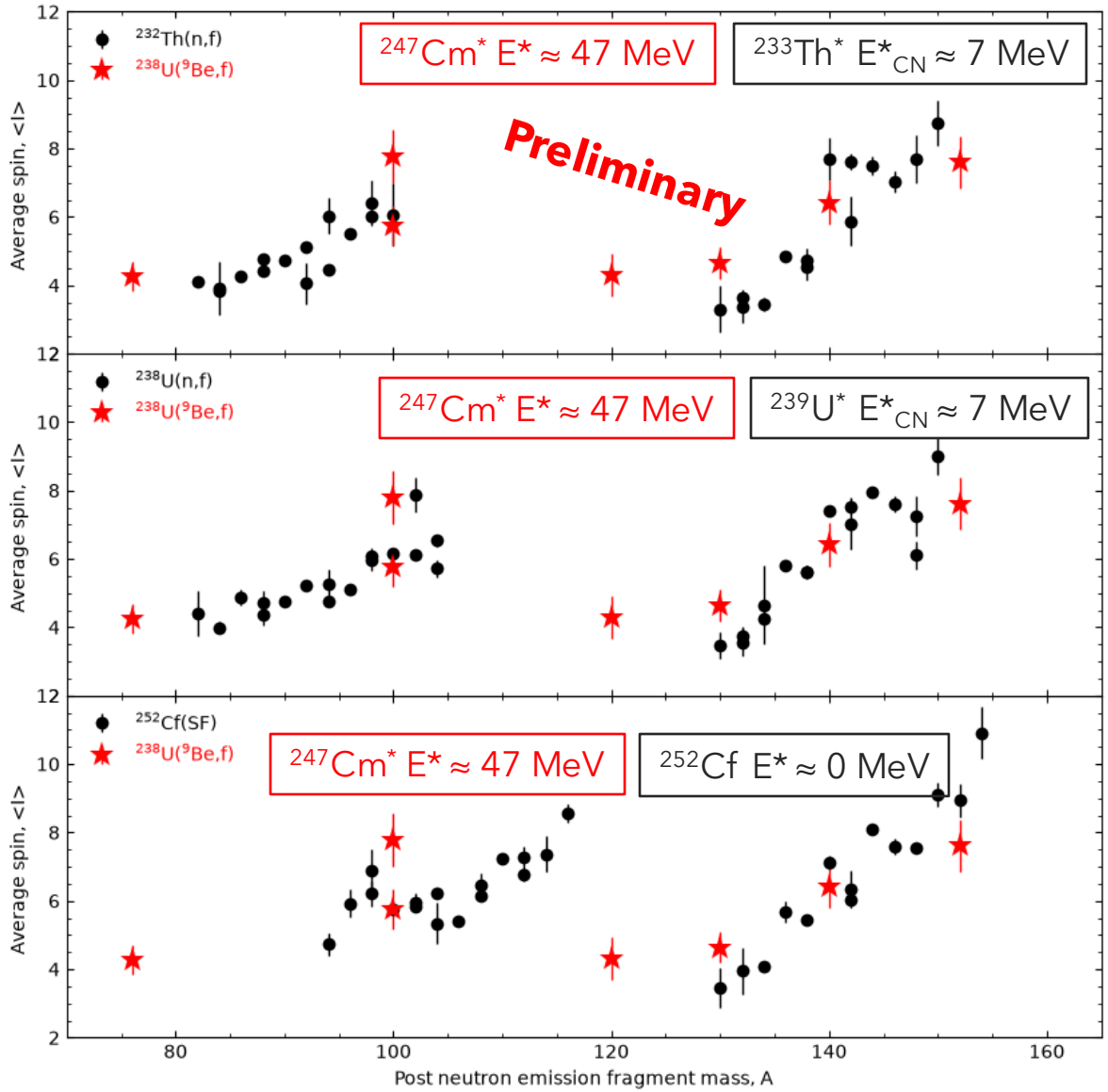
Outlooks:

- Extract <J> for all possible isotopes (limitations : level-scheme, long-lived isomers & statistics)
- Systematic study/comparison as a function of A, Z, N



Conclusion & Outlooks

Thank you for your attention!



S. Lenzi, E. Clément & A. Gadea "The AGATA Physics Campaign In GANIL: Results And Perspectives". *Proceedings of science (2016)*

Z distribution