Study of isomers in ^{165}W and ^{169}W

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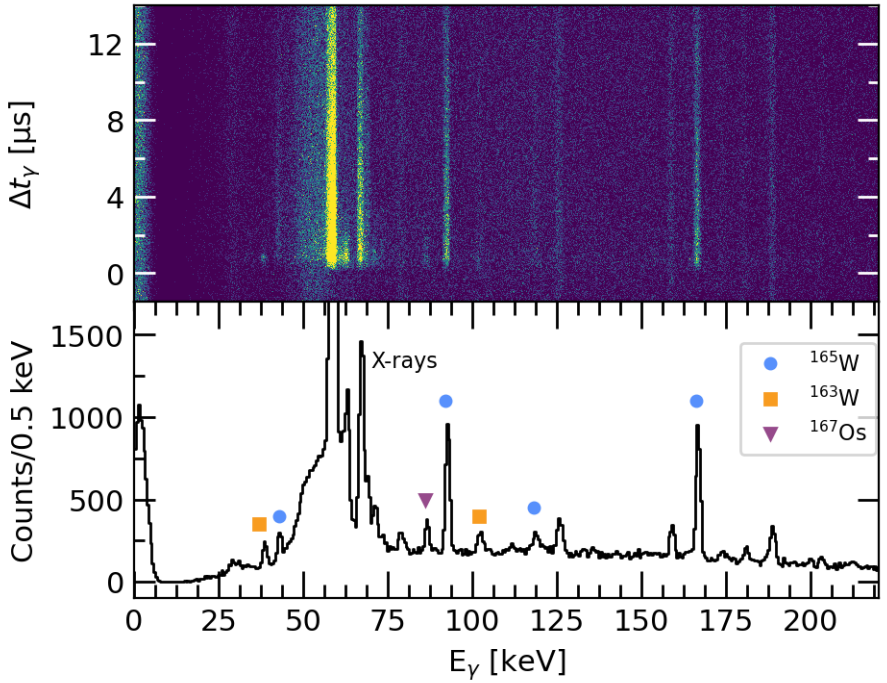
Chalmers University of Technology
Experimental Subatomic Physics

8th of May 2026
15th Nordic Meeting on Nuclear Physics

Unexpected data – background of the experiments



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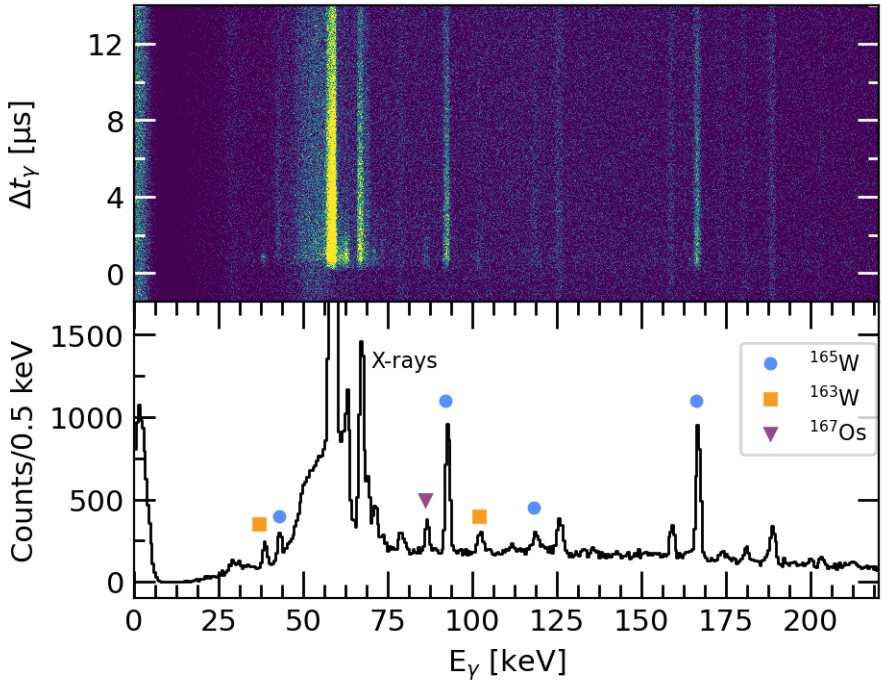

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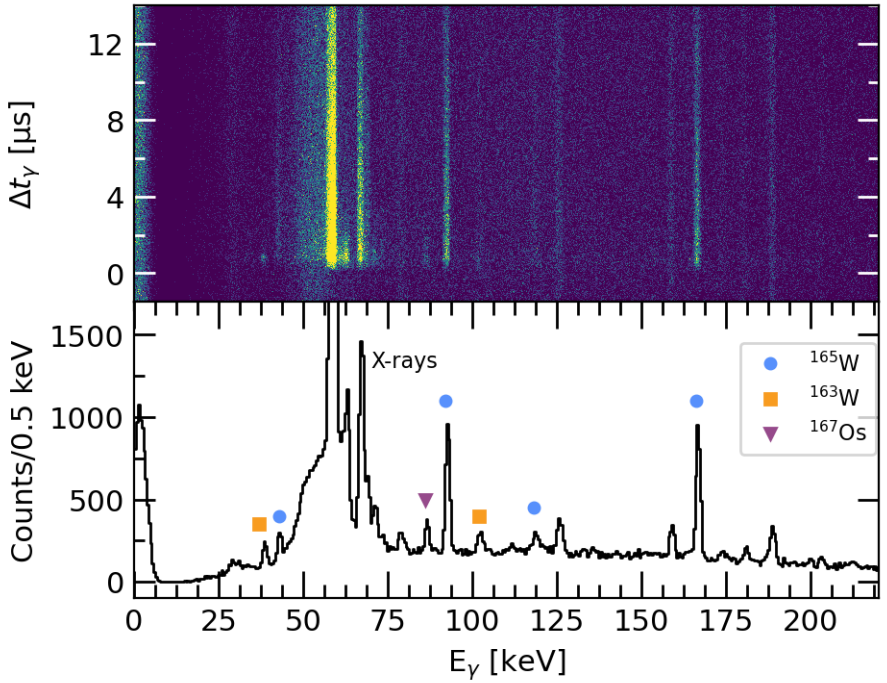

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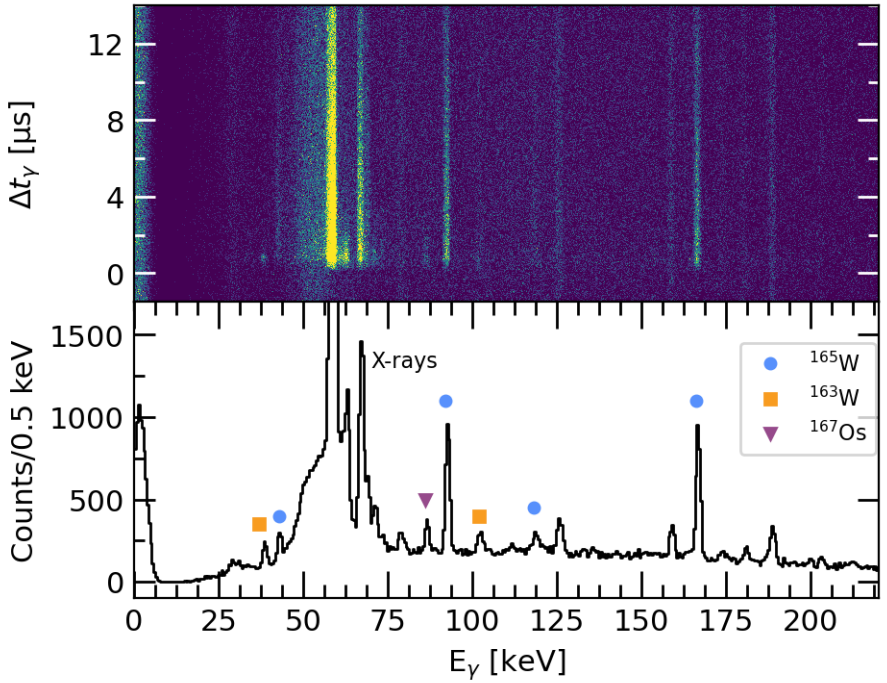

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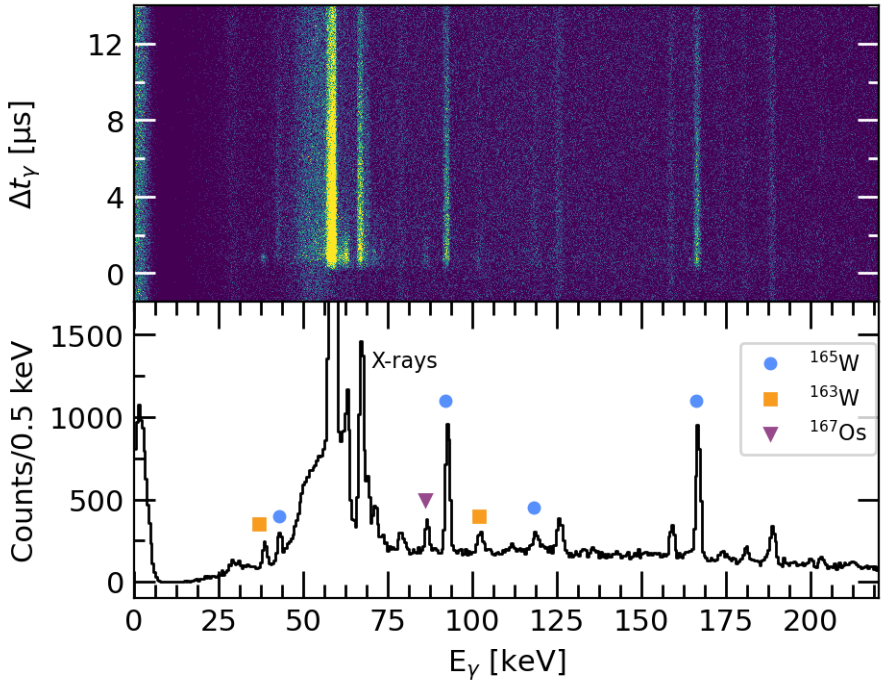

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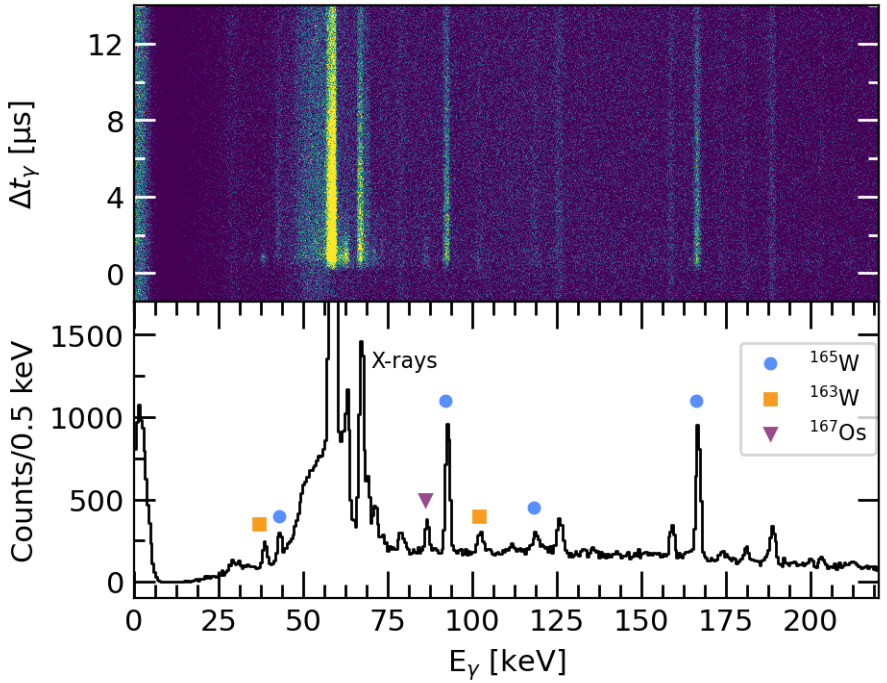

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^{165}W ^{169}W

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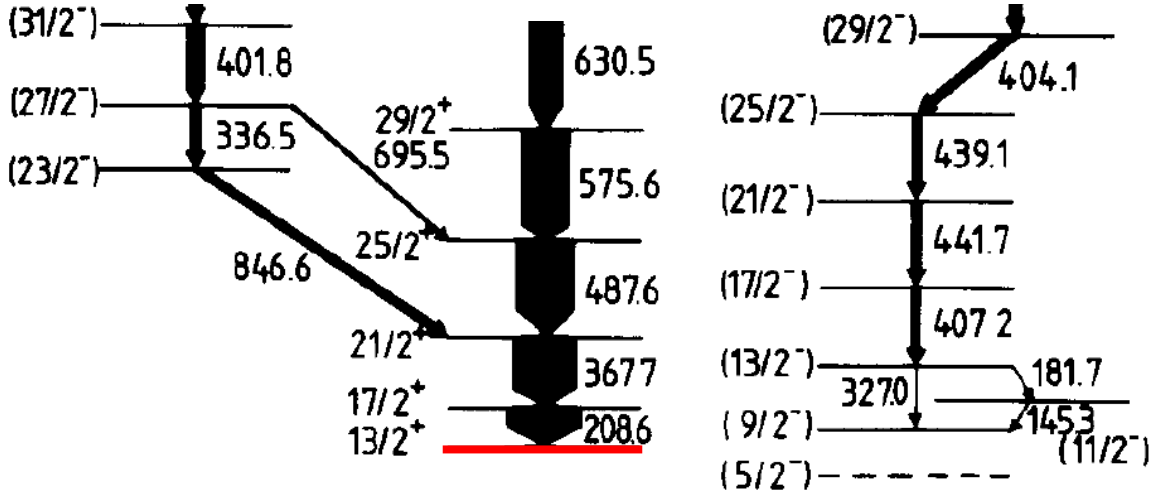

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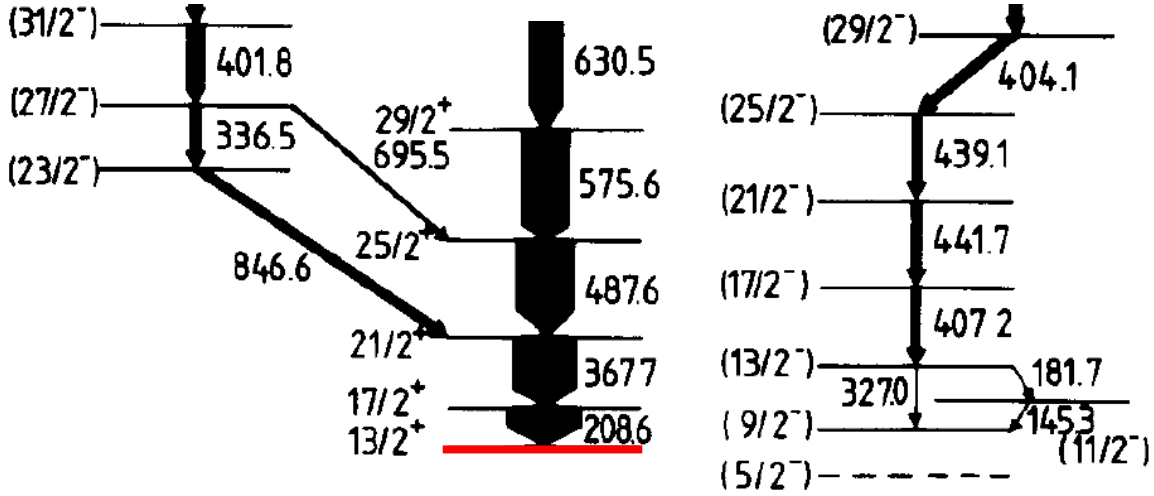

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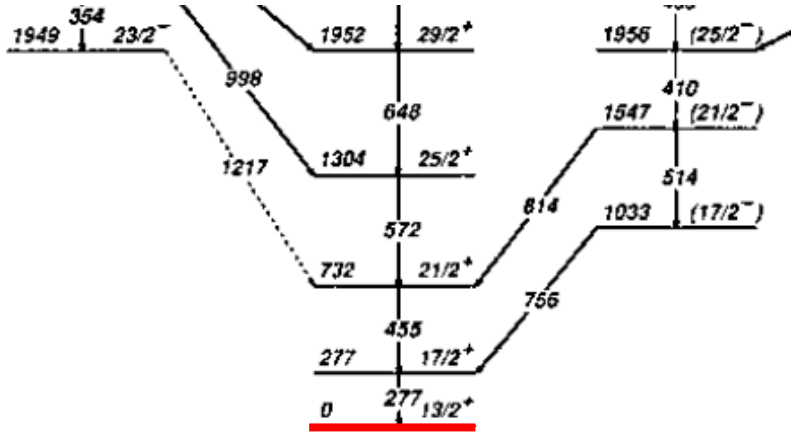

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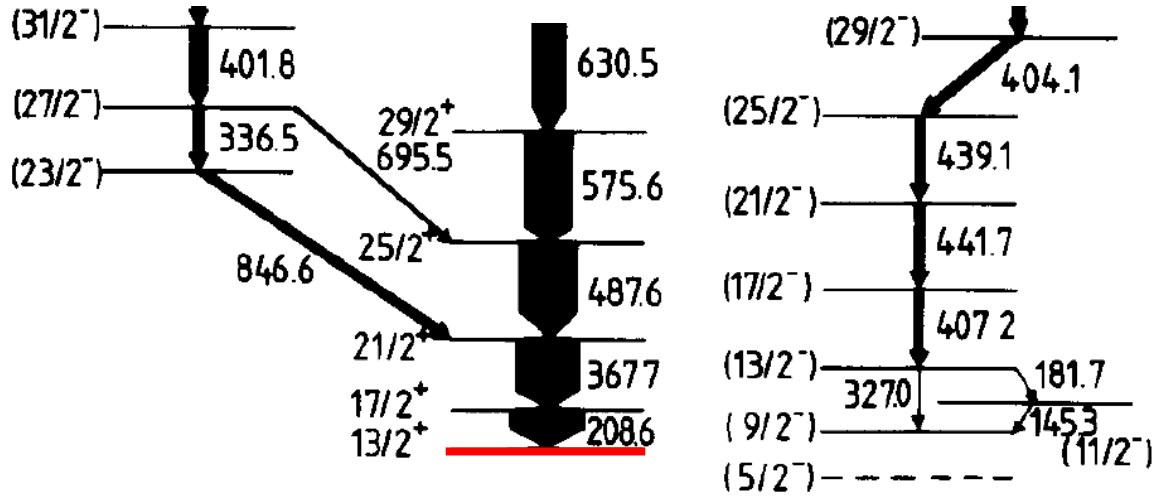

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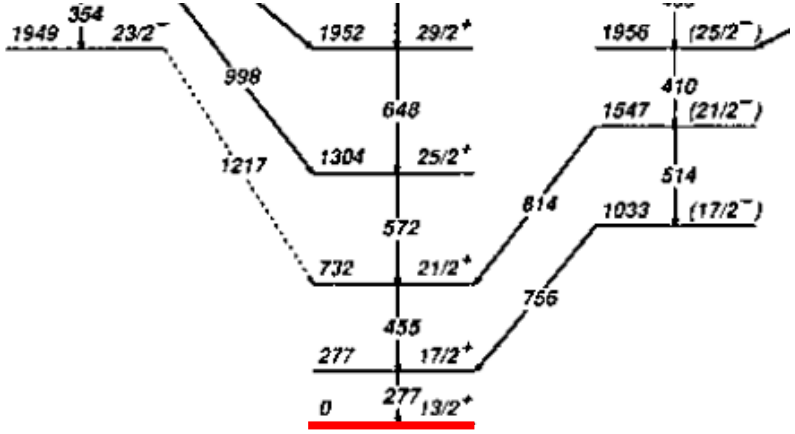

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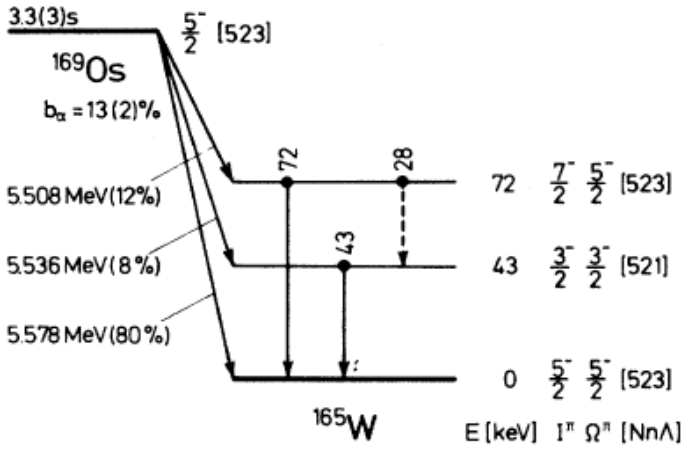

T. Hild et al., Phys. Rev. C 51, 1736 (1995)

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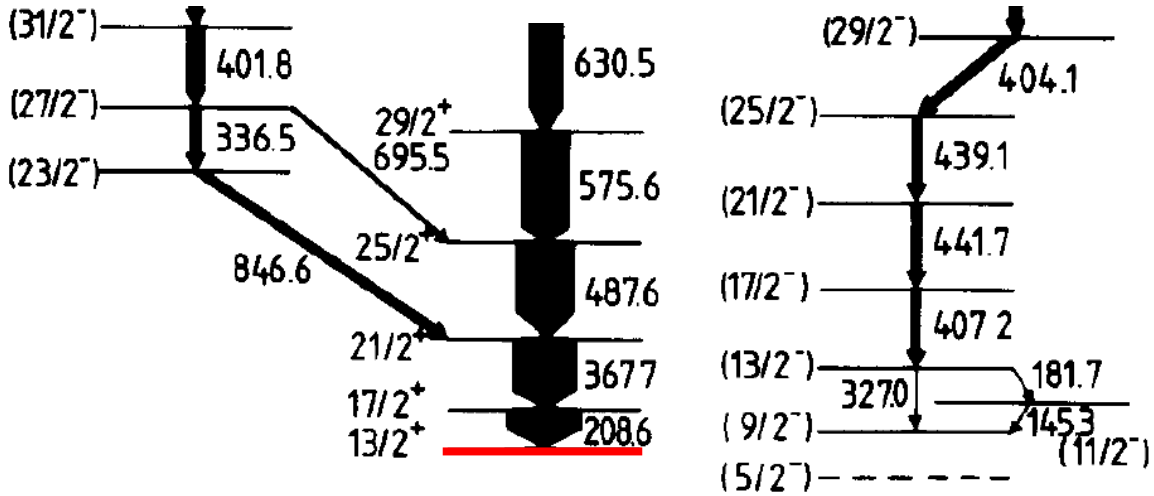

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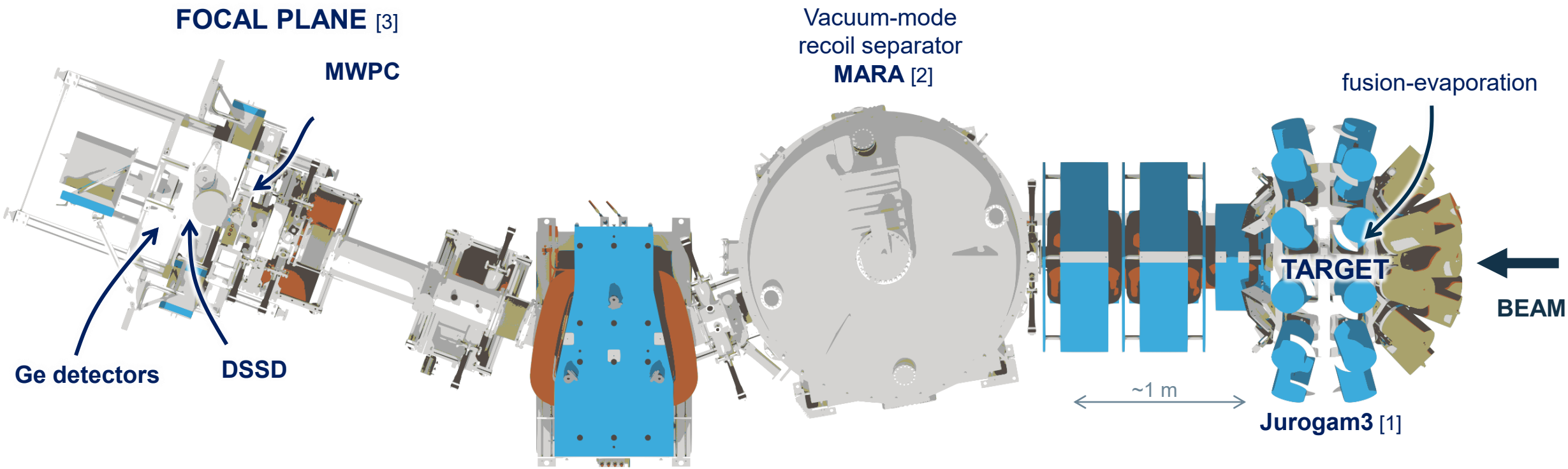
Overview of the setup



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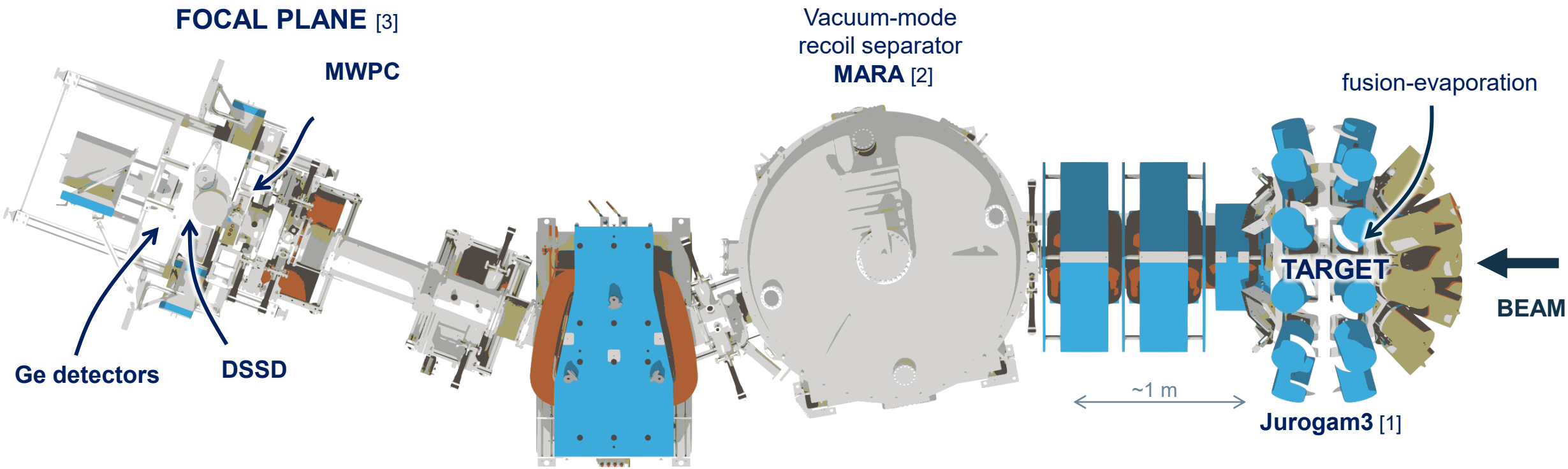

- ^{92}Mo(^{78}Kr, 4p1n)^{165}W @ 380 MeV for 8 hours
- ^{92}Mo(^{84}Kr, 1α2p1n)^{169}W @ 402 MeV for 16 hours

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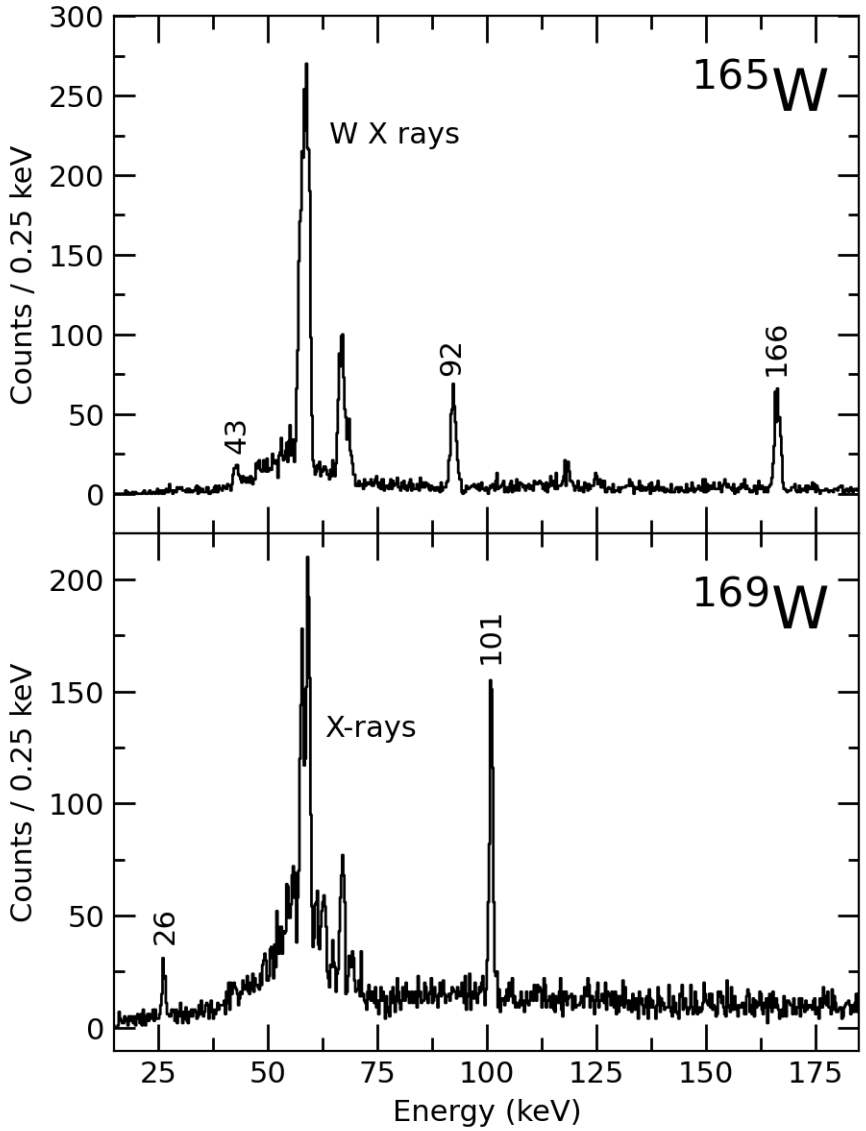
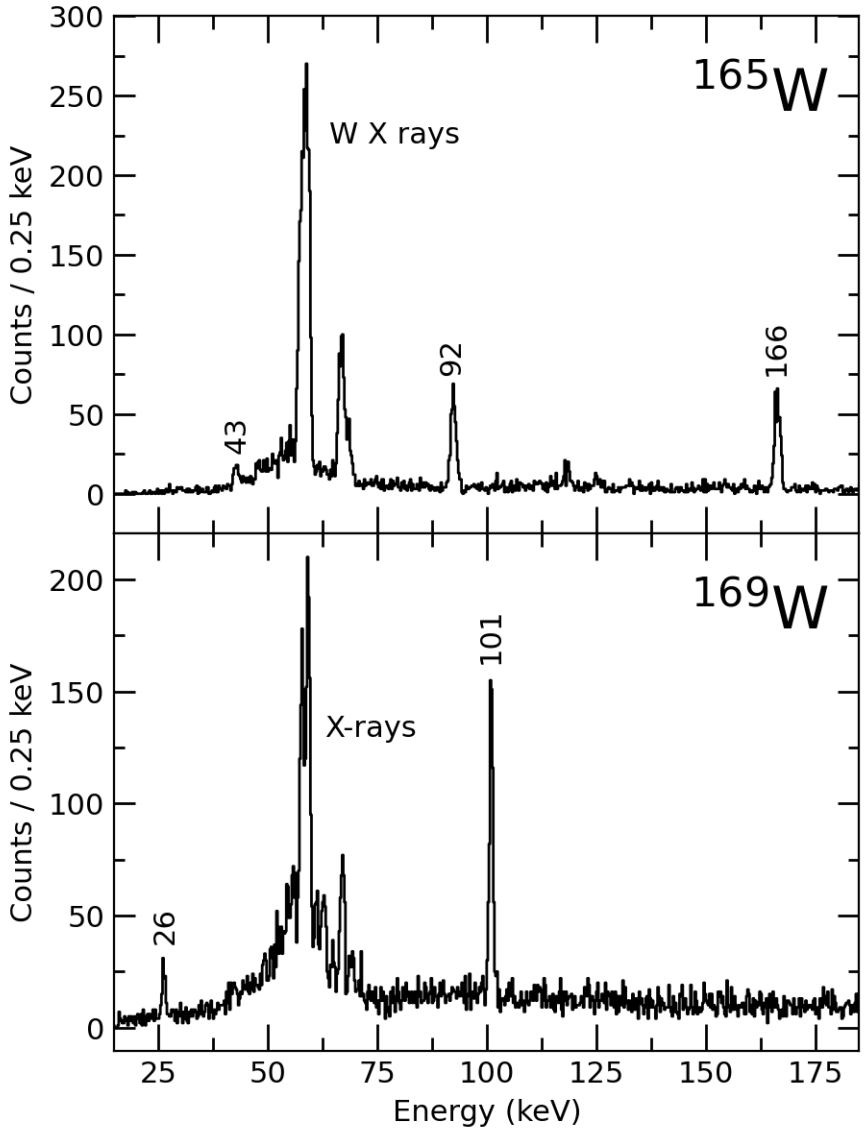
Observed at the focal plane



Delayed γ-ray energy spectra for the two experiments gating on prompt γ rays in JUROGAM 3.



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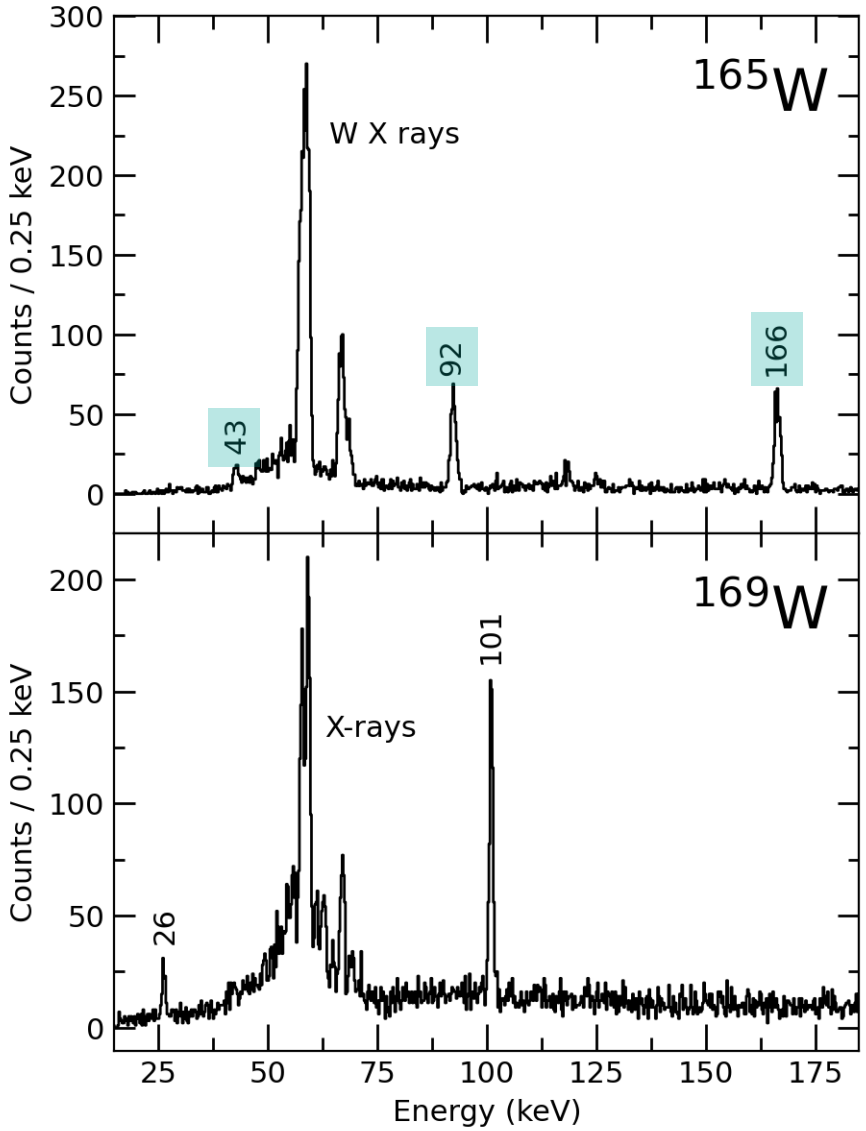

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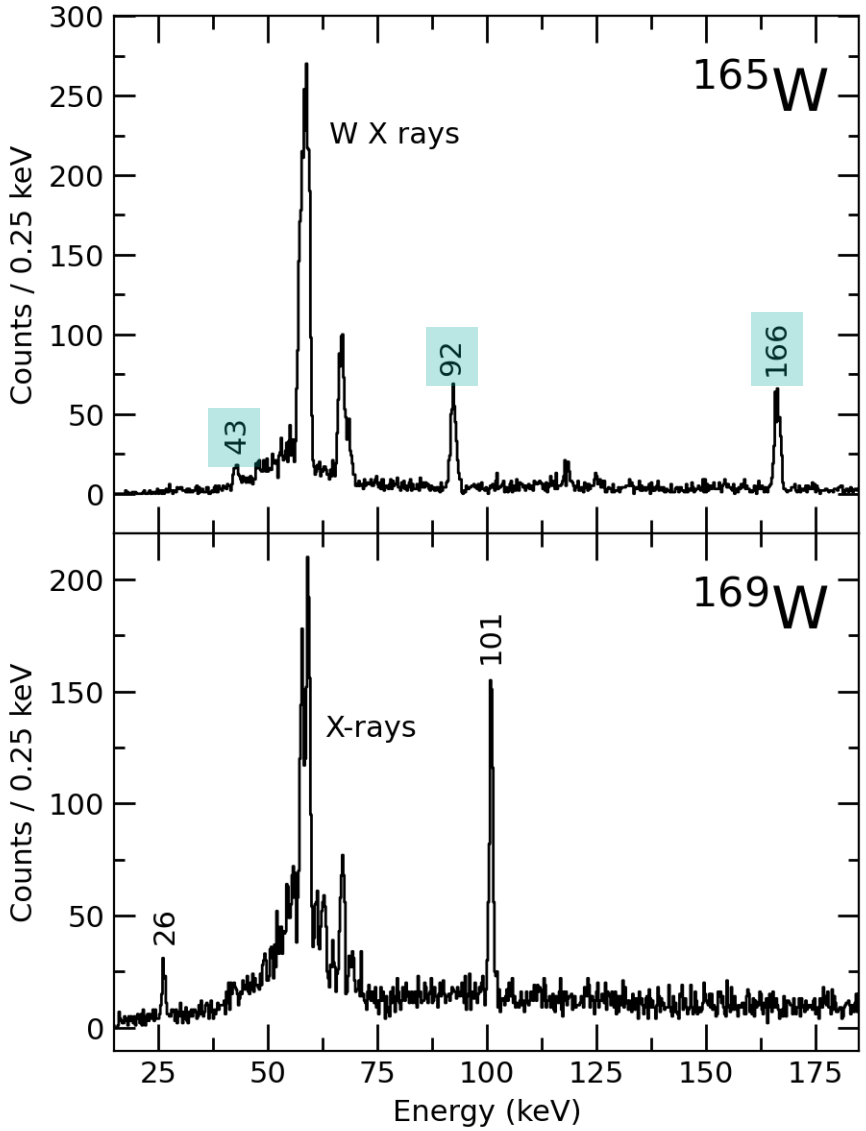

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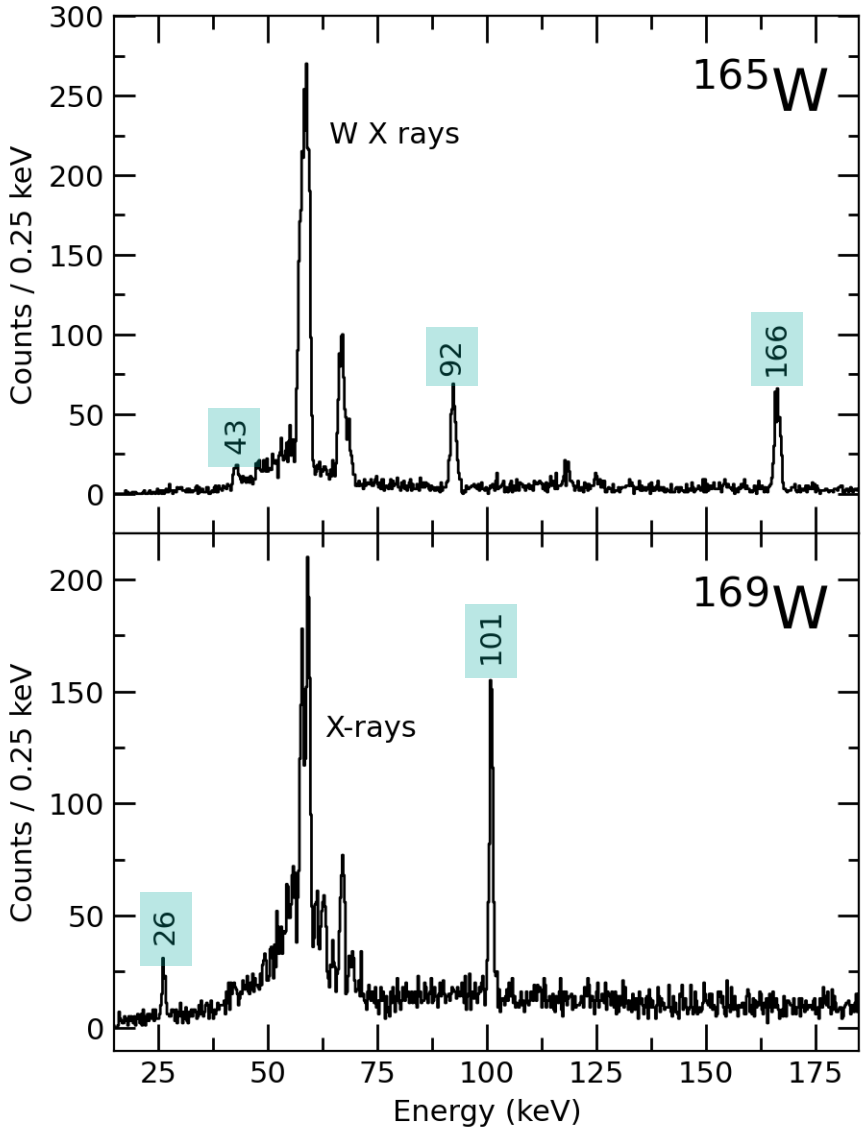

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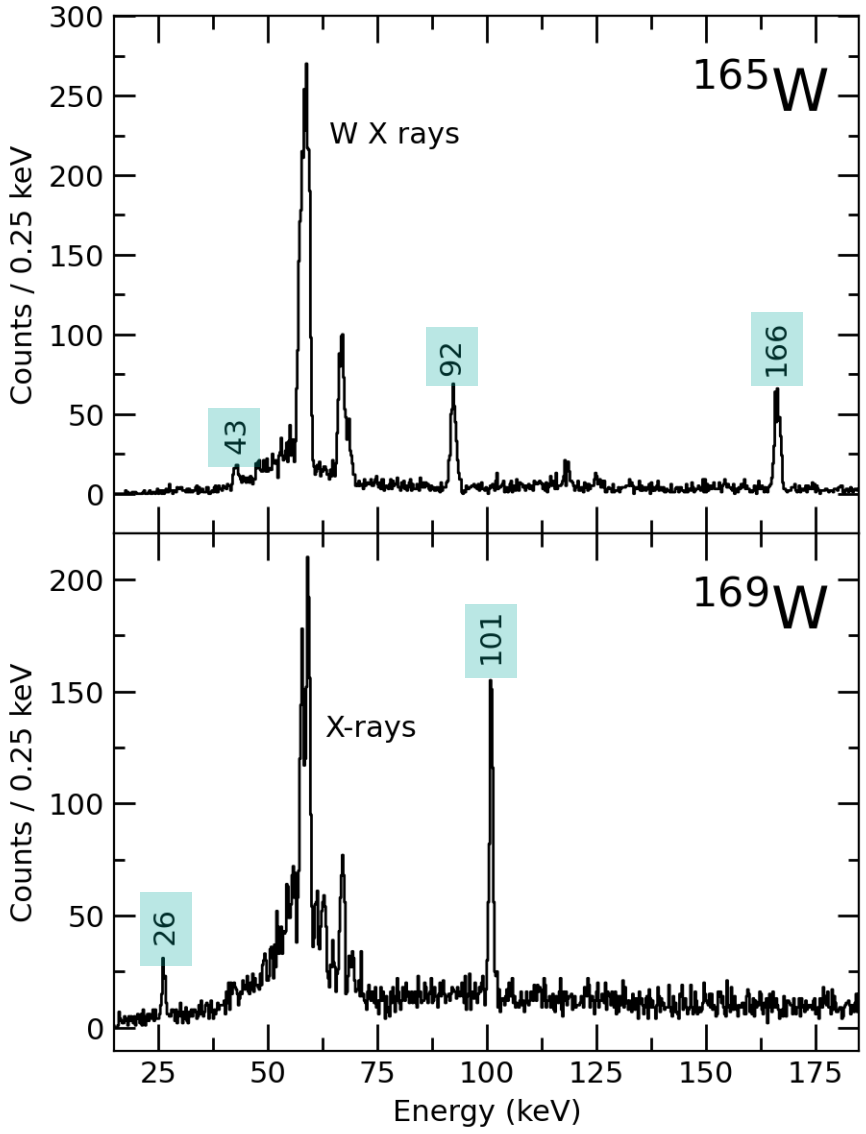

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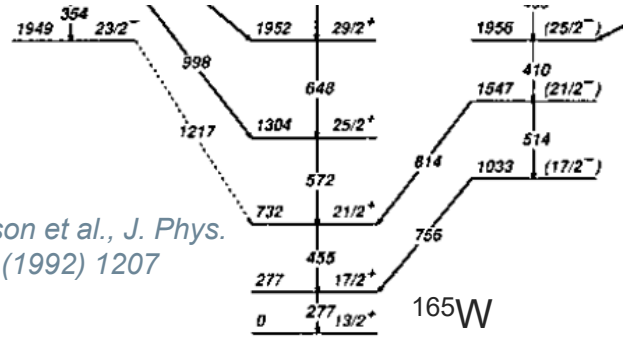

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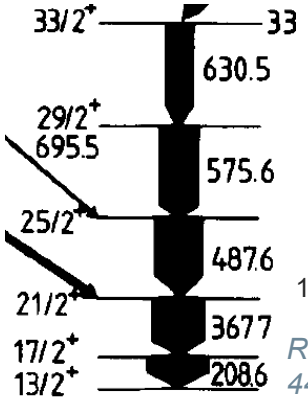

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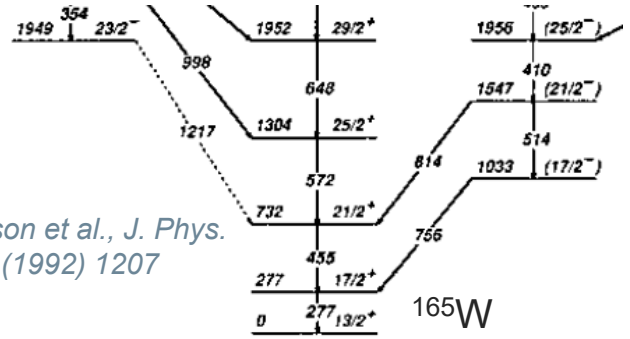

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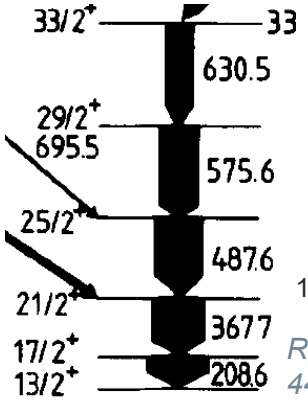

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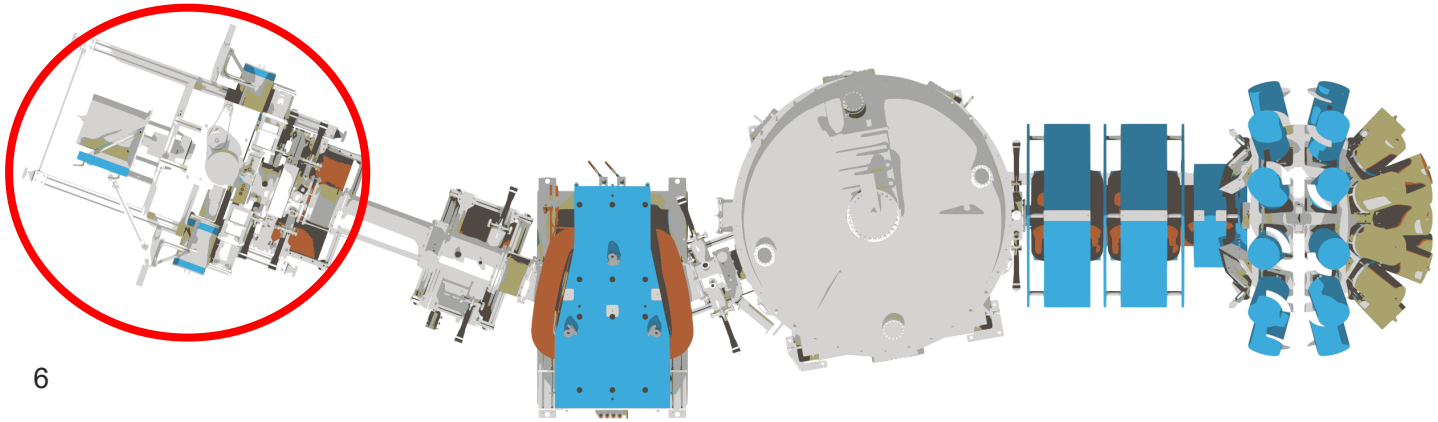

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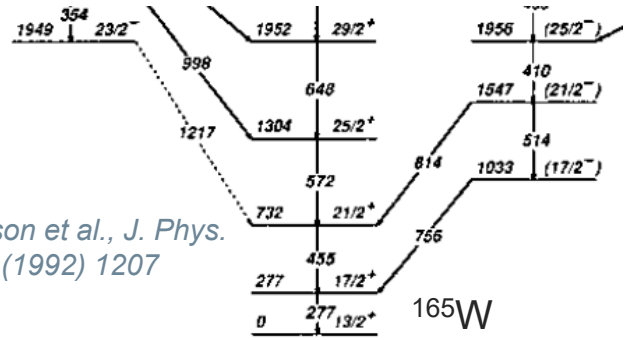

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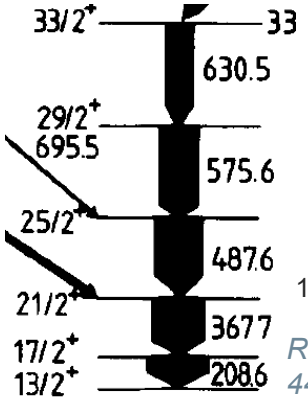

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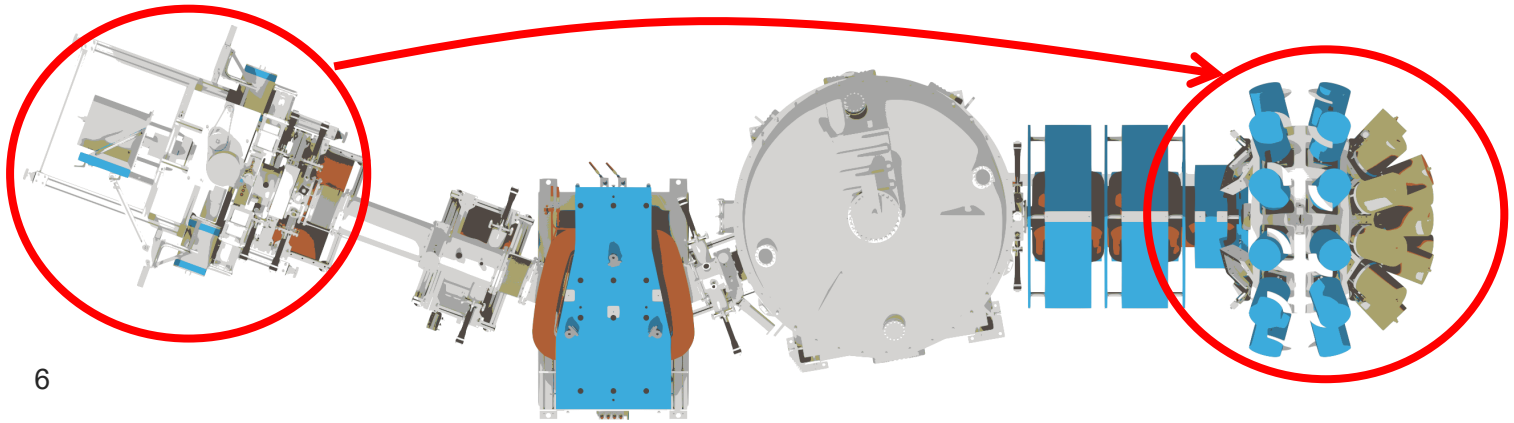

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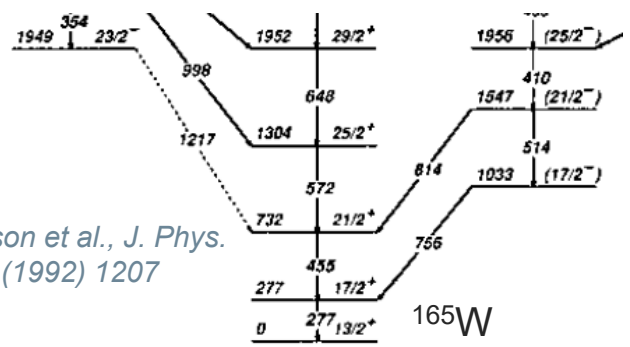

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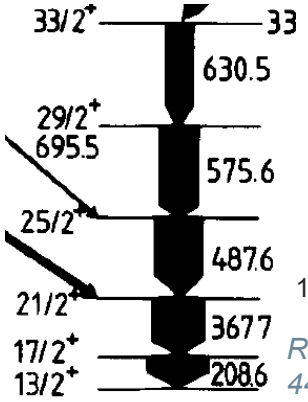

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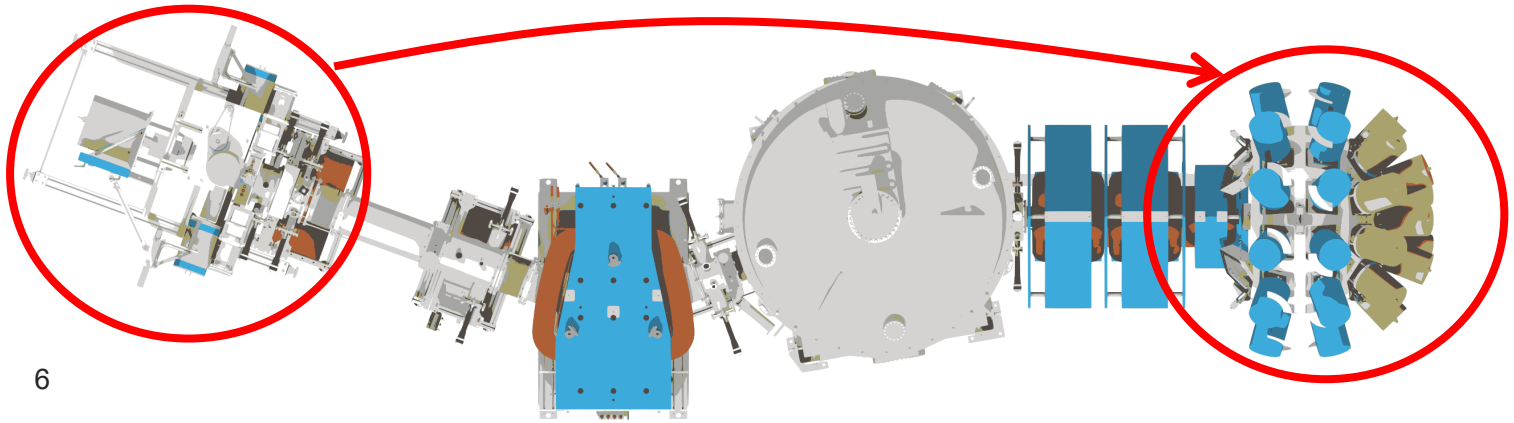

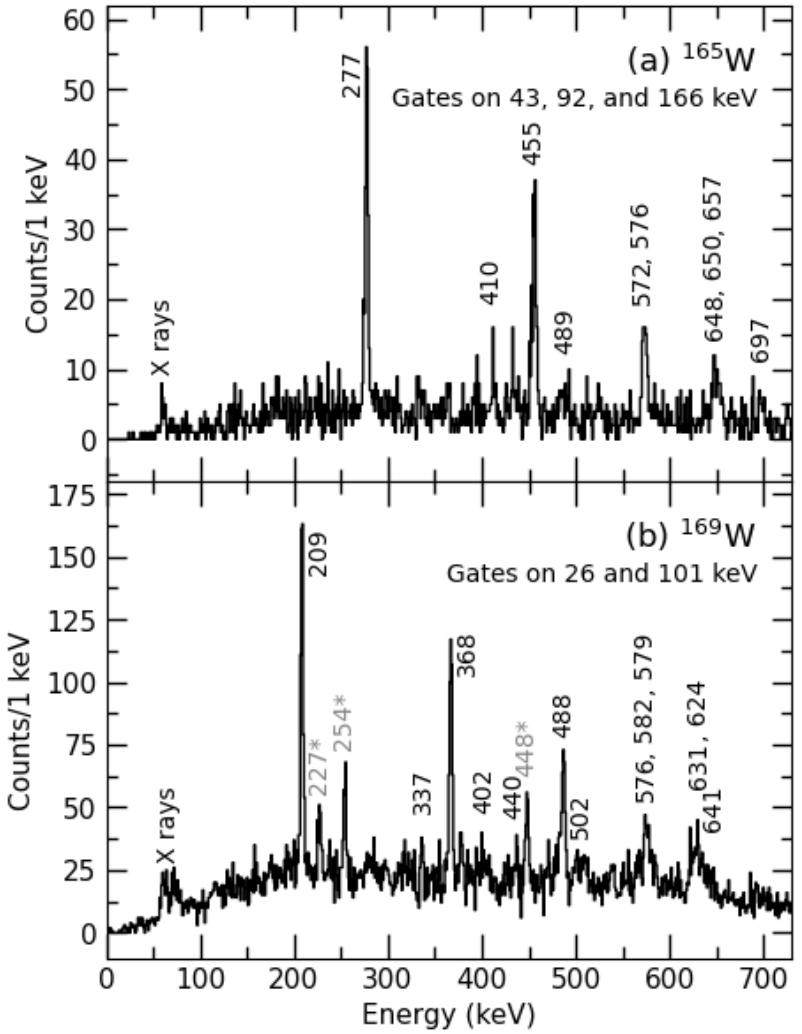

Recoil-isomer tagged JUROGAM 3 energy spectra for the two cases.

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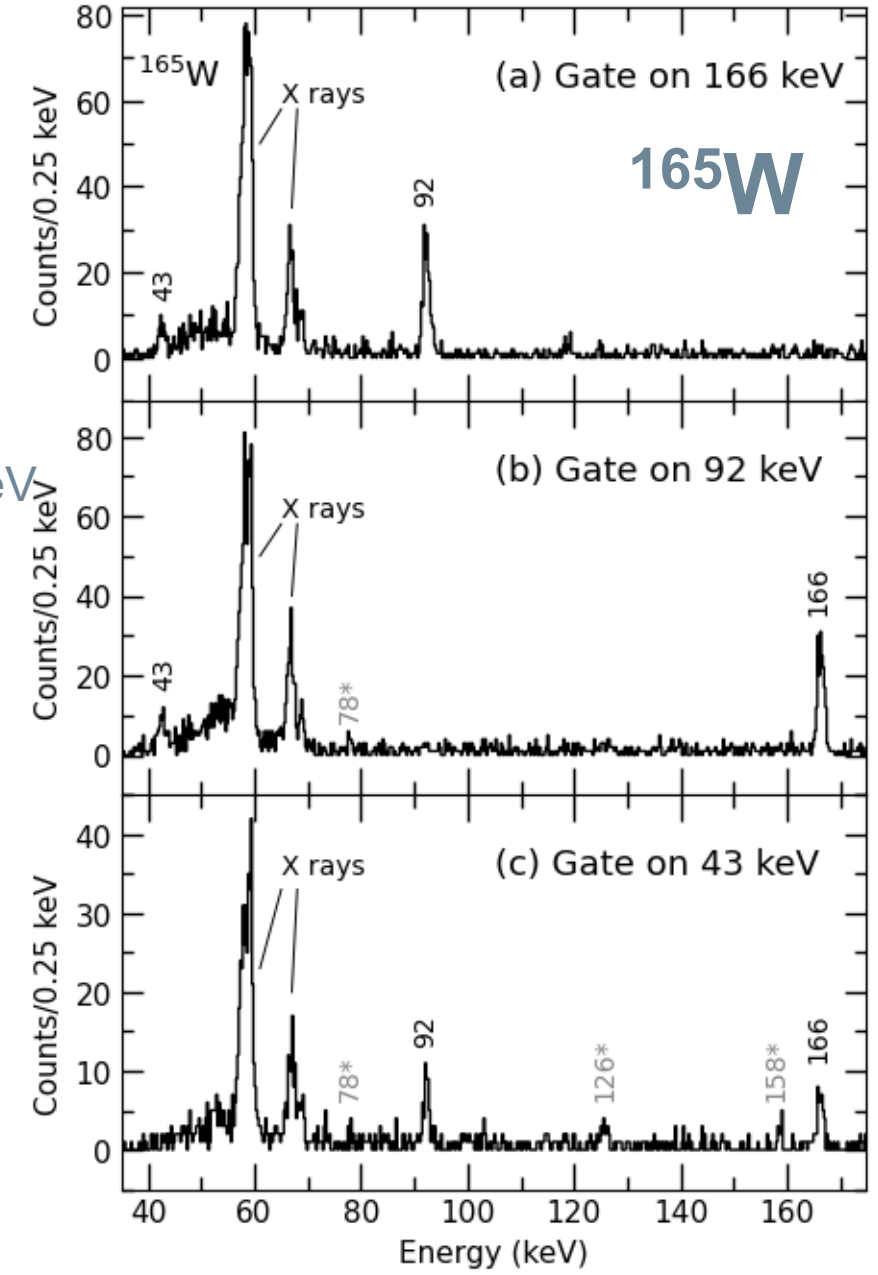

γ-γ for transitions in ^{165}W.

Identifying the nuclei

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- X rays in coincidence at the focal plane
- Comparison of *A/q* distributions at MWPC against known species

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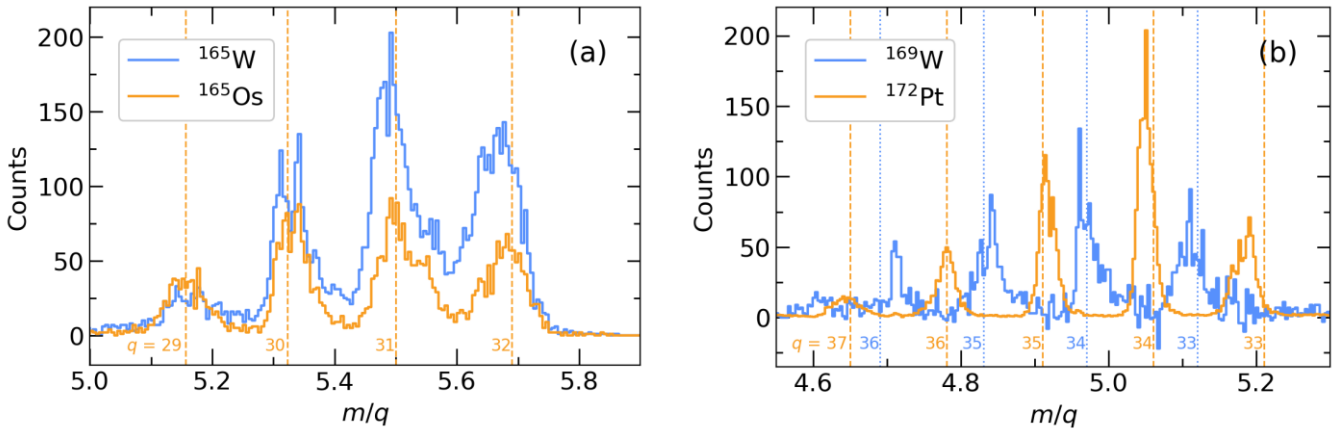
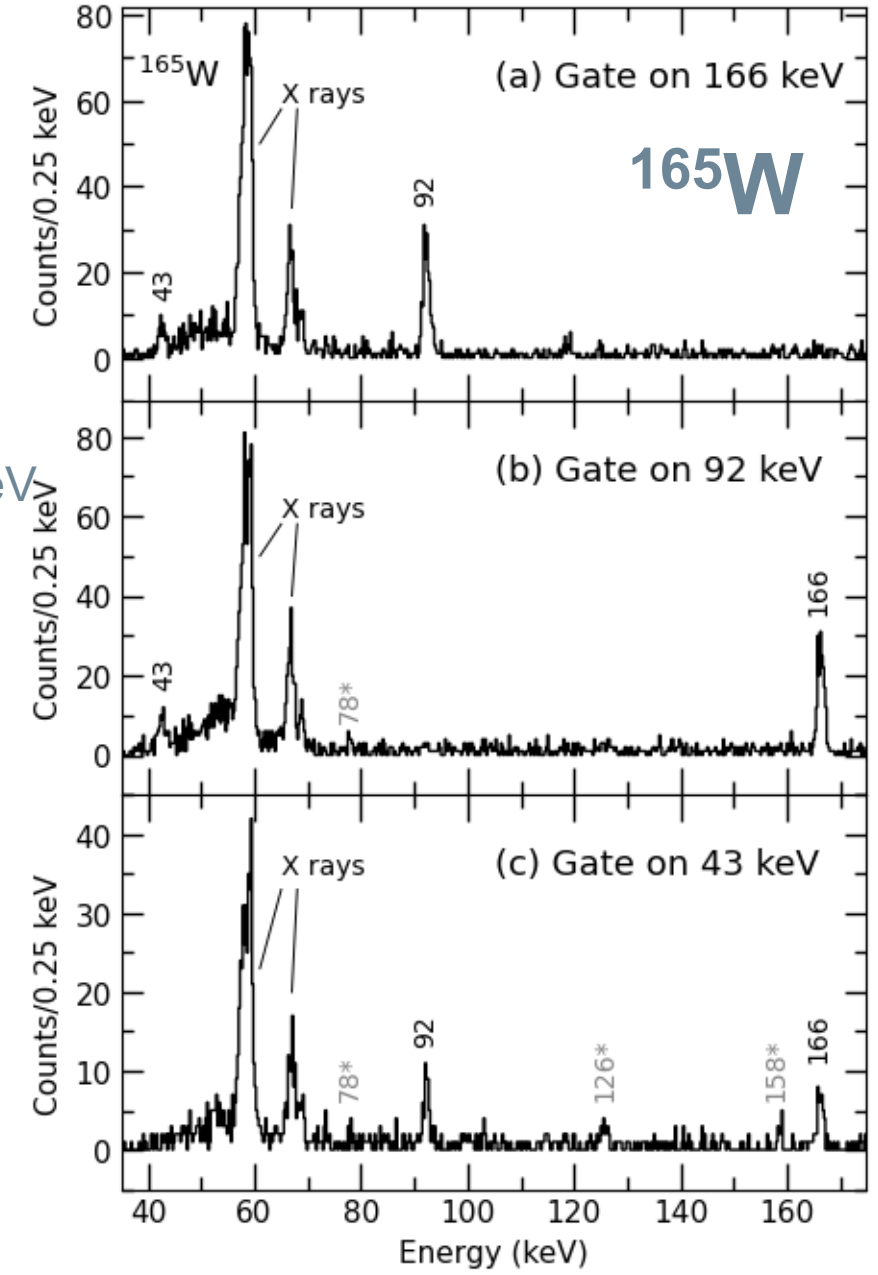


Distributions of the recoils measured by the MWPC in the two experiments. (a) ^{165}W. (b) ^{169}W.



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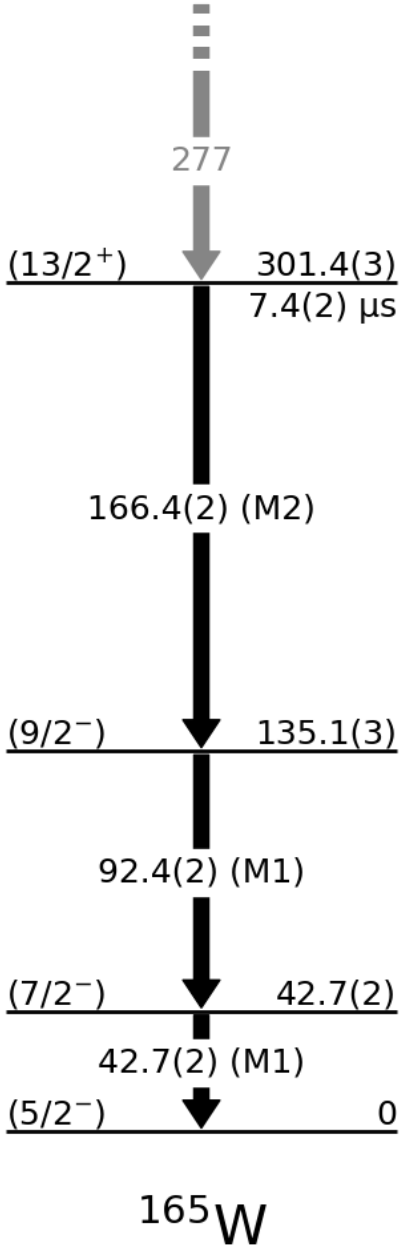

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Level schemes

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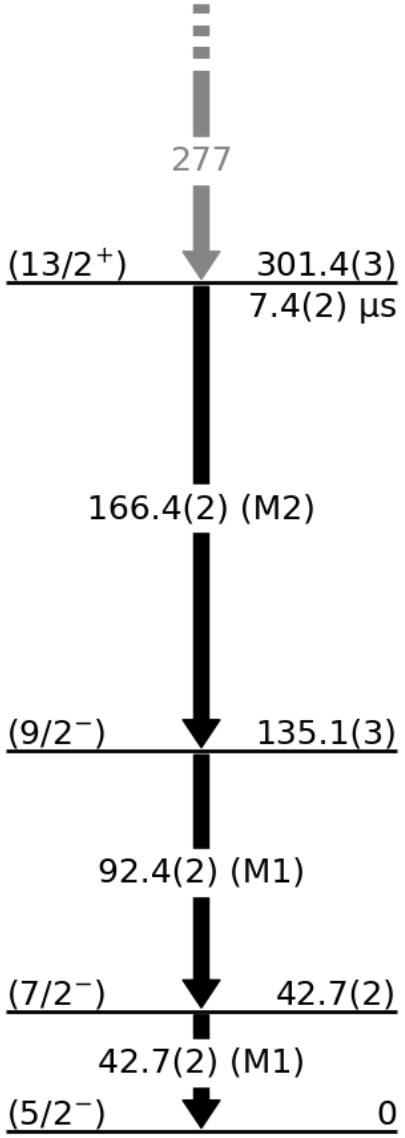
  - Add up multipolarities → (13/2$^+$)
  - This is the same as in the previous study of ^{165}W [1]
- ^{169}W
  - Add up multipolarities → (9/2$^+$)
  - Same area of nuclear chart; delayed *E1* γ rays originating from a 9/2$^+$ state
    → an unseen *E2* transition from the previously observed [2] 13/2$^+$ state?



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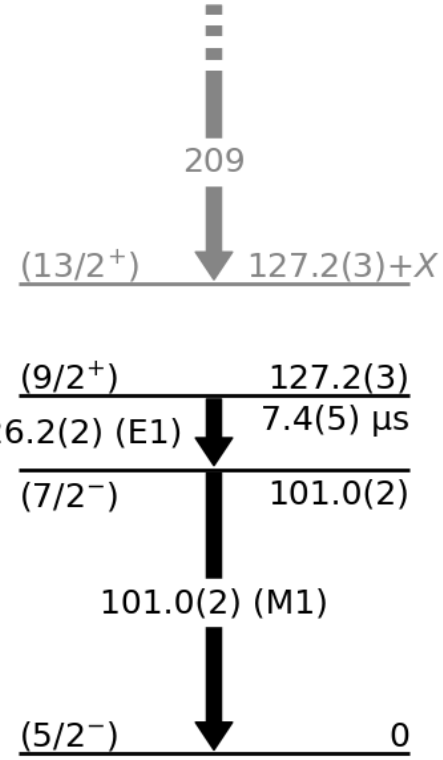

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  Hindrance values for *M2* isomers:
  - ^{167}Os: 5.62(9)
  - ^{161}Hf: 5.9(3)
  - ^{171}Pt: 2.25(3)
  - ^{173}Pt: 9.0(6)

→ Typical of hindrances between $i_{13/2}$ and $h_{9/2}$ orbitals

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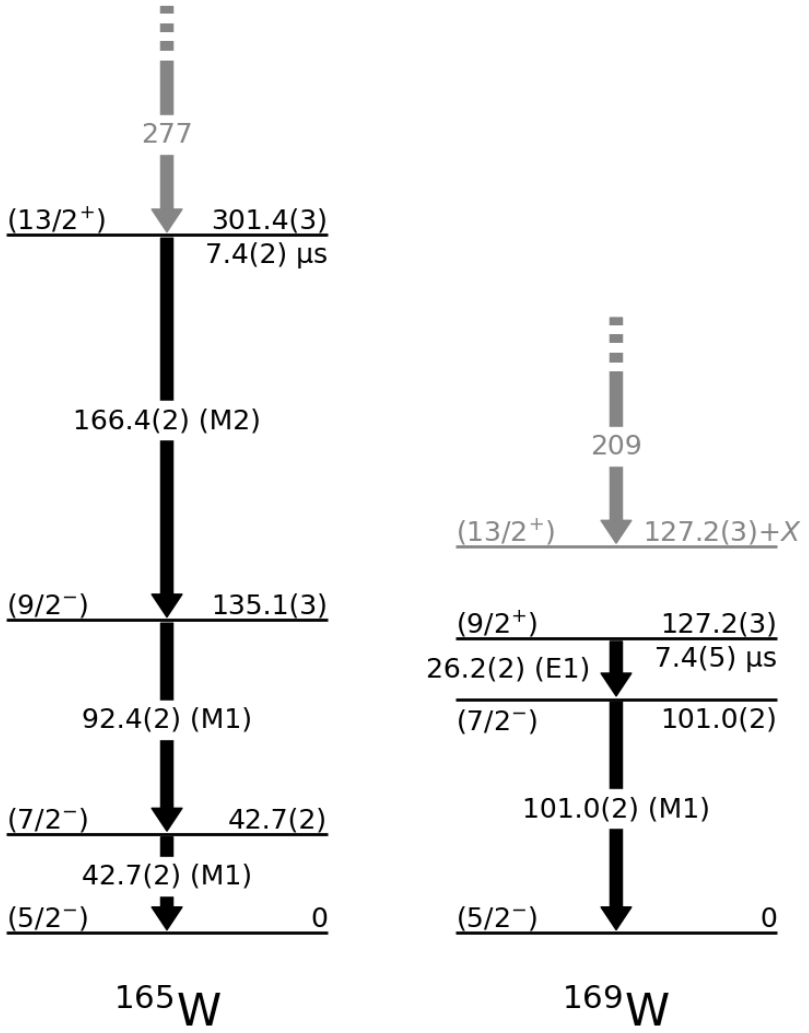
  Hindrance values for *E1* isomers:
  - ^{157}Dy: 2.0(4)×10^{5}
  - ^{169}Er: 1.37(14)×10^{5}
  - ^{161}Er: 4.6(2)×10^{4}
  - ^{165}Yb: 1.46(15)×10^{5}
  - ^{173}Os: >1.7×10^{6}

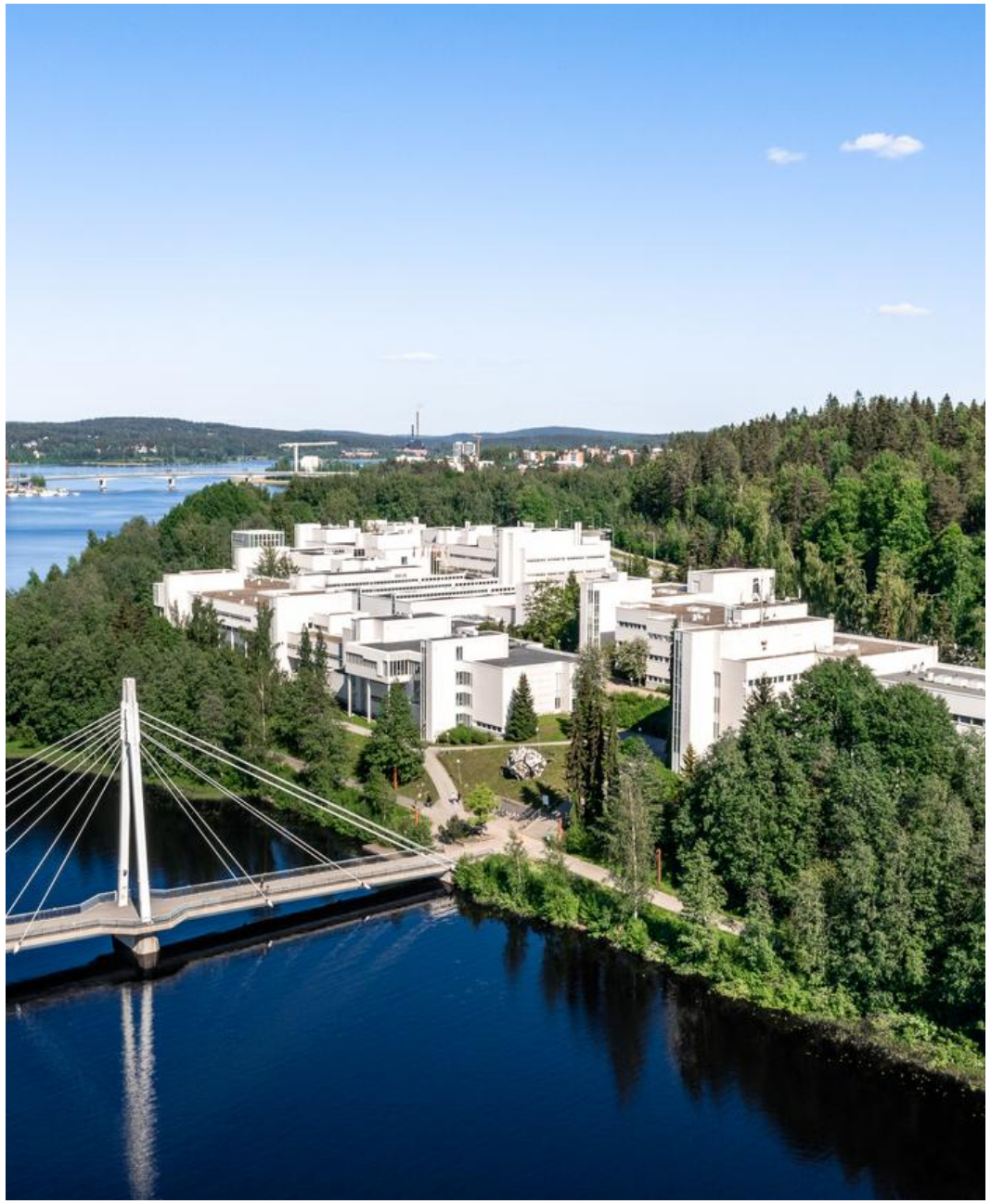
→ Order of magnitude larger (except perhaps with ^{173}Os)
- Composition of the states in ^{169}W (and ^{173}Os) different from that in their neighbors?

To summarize

- **Structures below isomeric states in ^{165}W and ^{169}W have finally been observed**
  - Thanks to advancements in detectors, data collection, techniques…
- **Transitions observed up to (13/2$^+$) in ^{165}W**
  - Excitation energies have been set and previous spin assignments [1] confirmed for ^{165}W
  - Hindrance factor similar to others
- **Transitions observed up to (9/2$^+$) in ^{169}W**
  - Unobserved *E2* transition between the previous band structure by Ref. [2] and the (9/2$^+$) state
  - Isomer more hindered than usually?
- **Publication incoming…**



[1] R. S. Simpson et al., J. Phys. G 18, 1207 (1992)
[2] J. Recht et al., Nucl. Phys. A 440, 366 (1985)



Backups…

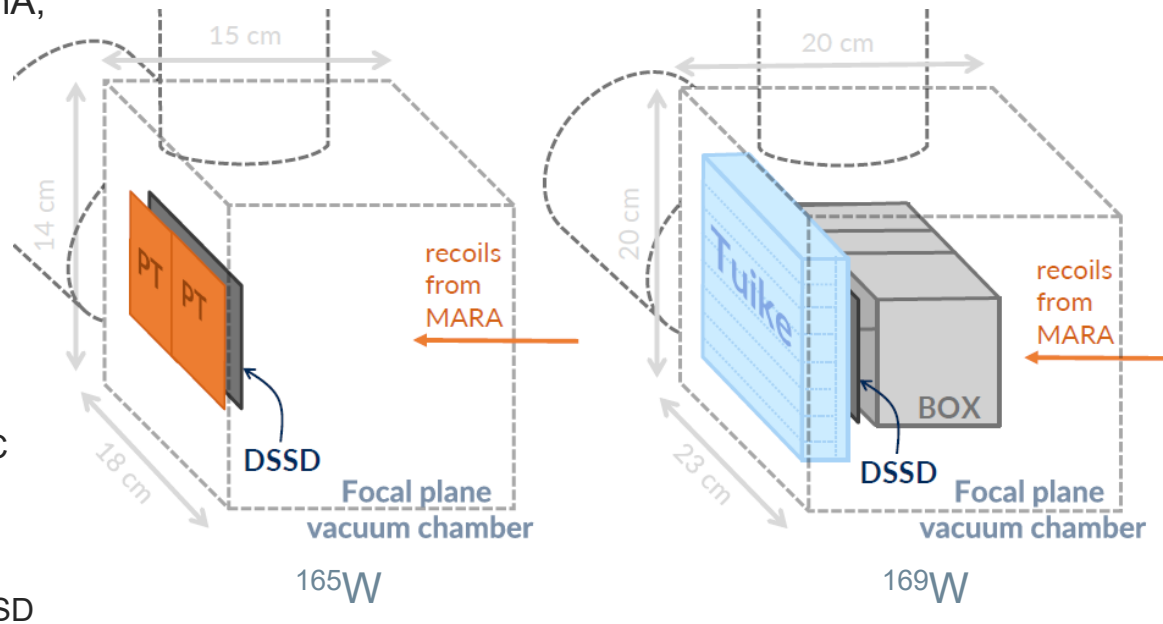
Differences in the two experiments

^{165}W

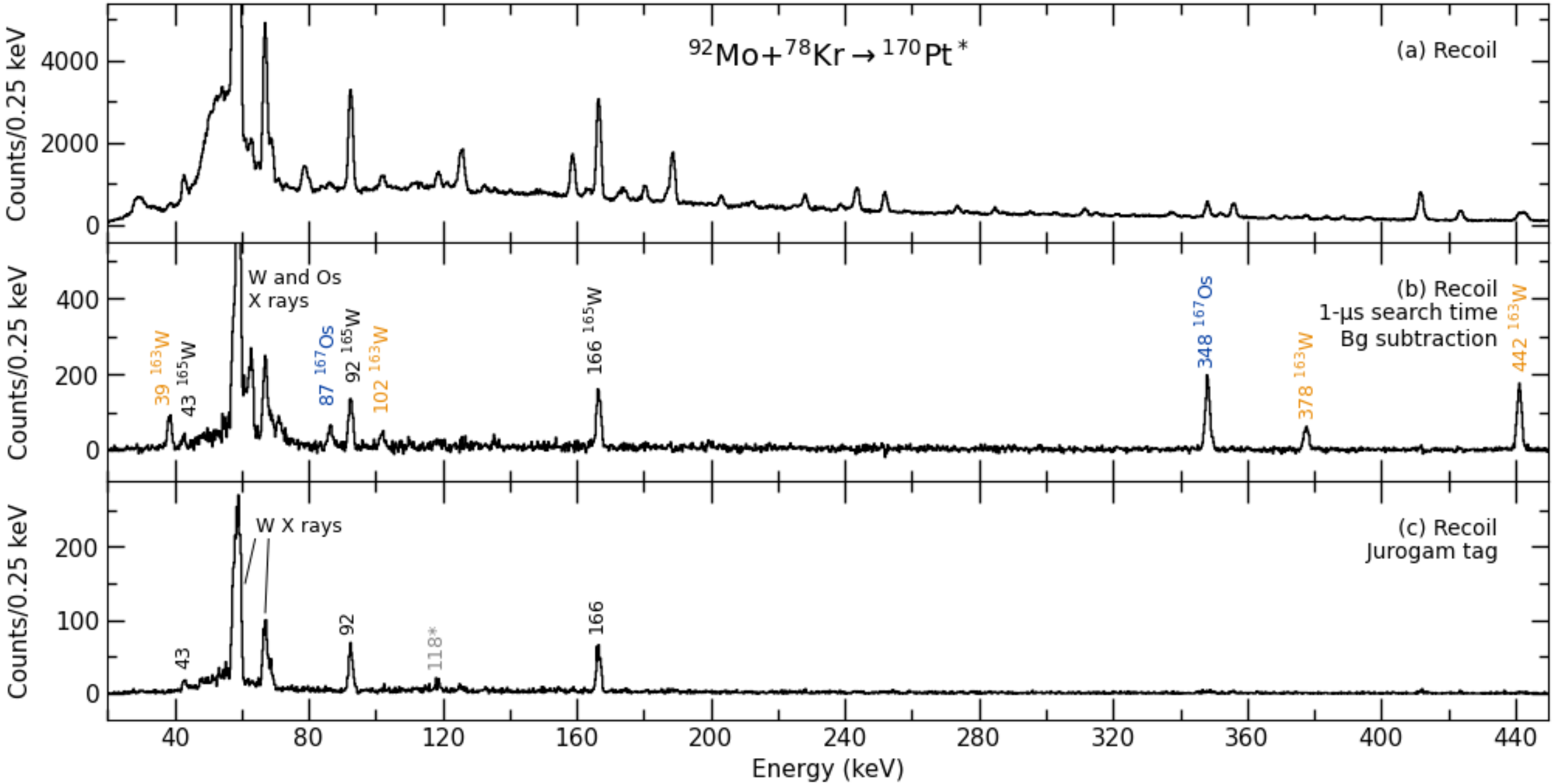
- ^{78}**Kr** beam (**380 MeV**, 4.6 pnA, 8 hours)
- ^{92}Mo target (0.55 mg/cm^2)
- Setup
  - JUROGAM 3
    - 15 tapered germanium detectors + Compton suppression
  - Focal plane
    - DSSD (**150 µm**) + MWPC
    - 3 BEGes + **Clover**
    - Two 1-mm silicon detectors downstream of DSSD

^{169}W

- ^{84}**Kr** beam (**402 MeV**, 4.7 pnA, 16 hours)
- ^{92}Mo target (0.6 mg/cm^2)
- Setup
  - JUROGAM 3
    - 15 tapered, **24 Clover** germanium detectors + Compton suppression
  - Focal plane
    - DSSD (**300 µm**) + MWPC
    - 3 BEGes
    - Silicon detector tunnel upstream of DSSD
    - Tuike downstream of DSSD
      → **larger vacuum chamber**



More on the general focal plane setup:
J. Sarén et al., Nucl. Instrum. Methods Phys. Res. B 541, 33 (2023)


^{92}Mo+^{78}Kr → ^{170}Pt*
(a) Recoil
(b) Recoil
1-μs search time
Bg subtraction
(c) Recoil
Jurogam tag
W and Os
X rays
W X rays
39 ^{163}W
43 ^{165}W
87 ^{167}Os
92 ^{165}W
102 ^{163}W
166 ^{165}W
348 ^{167}Os
378 ^{163}W
442 ^{163}W
43
92
118*
166
Counts/0.25 keV
Energy (keV)

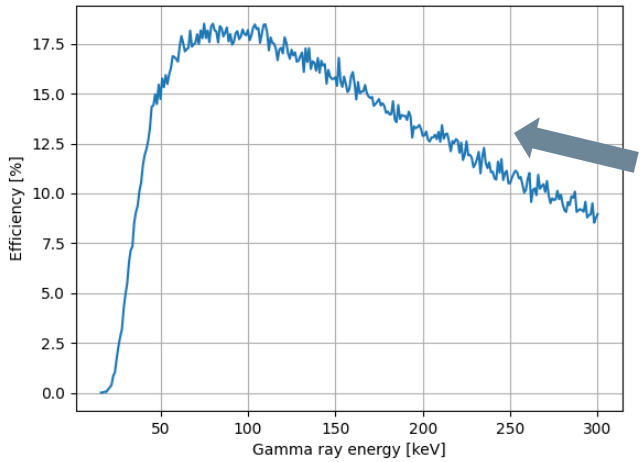
Solution: Estimations and assumptions

- Efficiency as a function of energy – shape
  - From simulations and past experience

  → Maximum of the efficiency curve appears in the 100 - 200 keV range
  - Energy ranges of interest:
    - X rays (55 - 70 keV)
    - γ rays (92 - 166 keV) → Efficiency greater than or equal to X-ray range

→ N_X/N_γ gives minimum α_K

- ^{165}W: 166 keV → *M2*
- ^{165}W: 92 keV → *M1*
- ^{165}W: 43 keV → *M1* from the previous study (Hild et al.)
- ^{169}W: 101 keV → *M1*
- ^{169}W: 26 keV → *E1* only possible



Our best from the simulation

Fit to data from few years earlier (slightly different positions)