Decay spectroscopy of ^{225}Pa : Study of octupole deformation in the neutron deficient actinides

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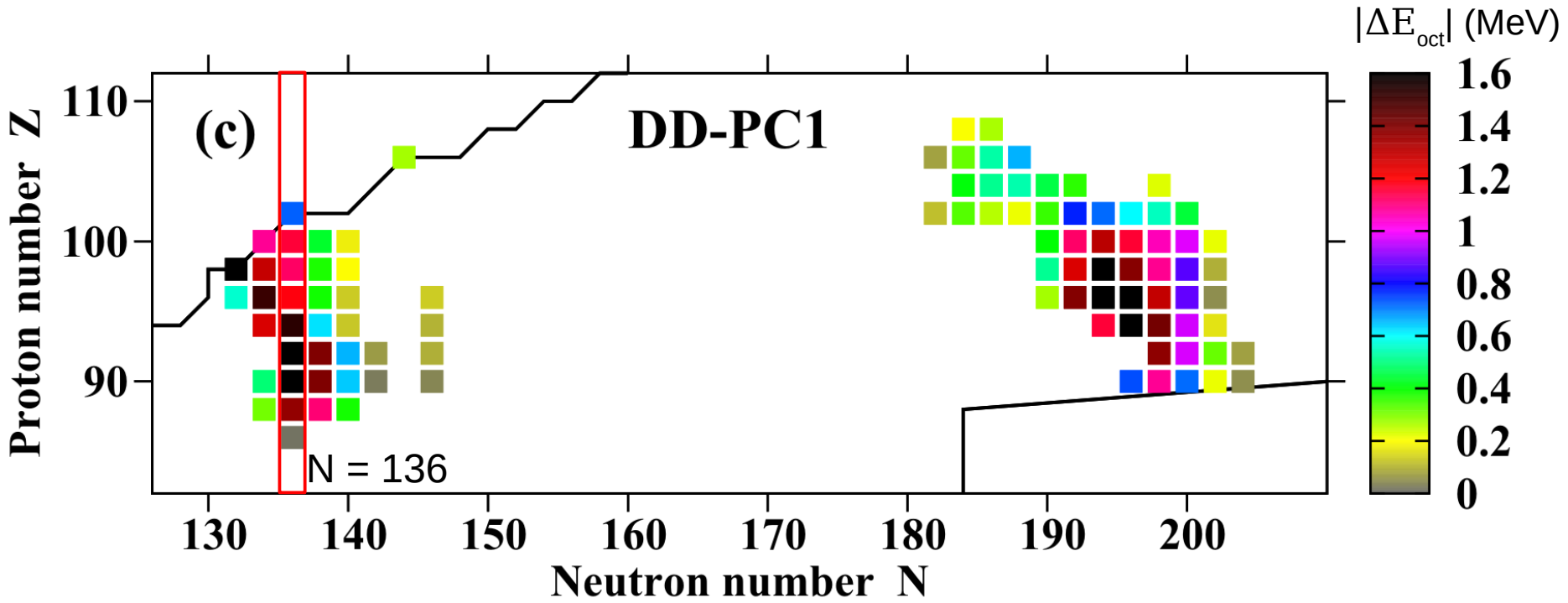
Colloque GANIL, September 29, 2023

université PARIS-SACLAY

ÉCOLE DOCTORALE
Particules, hadrons, énergie et noyau : instrumentation, imagerie, cosmos et simulation (PHENIICS)

Physics Motivations

Prediction of strong octupole deformations in the ground state of neutron-deficient actinides:



S. E. Agbemava et al. PRC 96 (2017)

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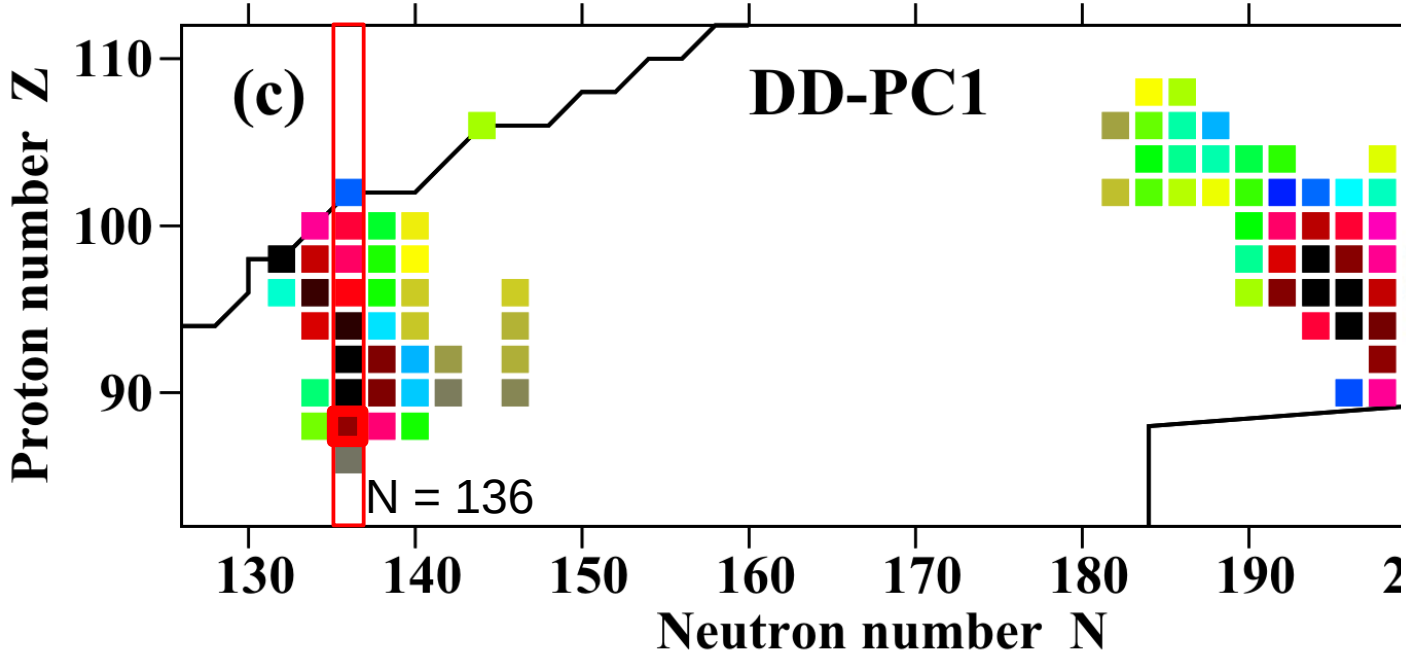

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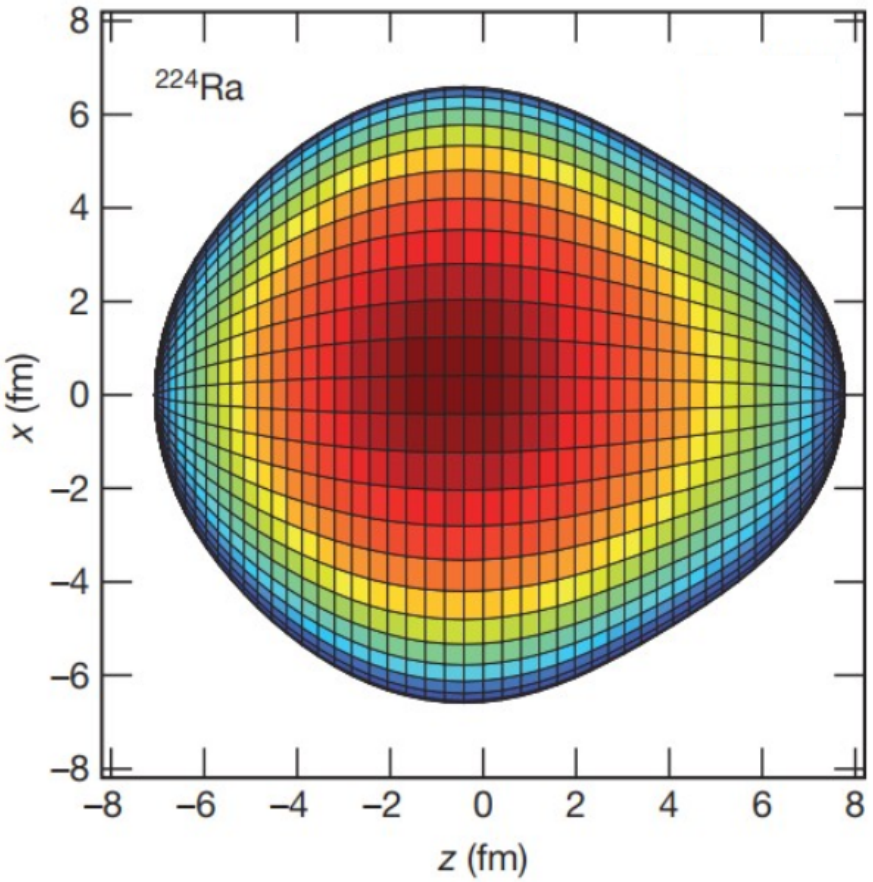
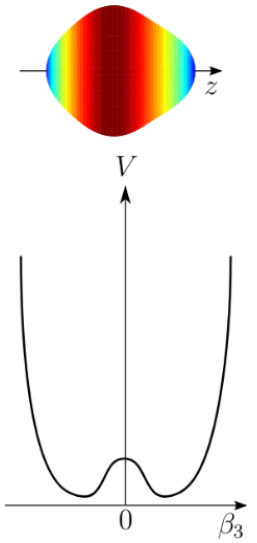


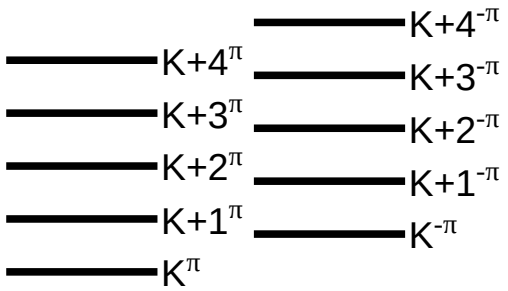
L. P. Gaffney et al. Nature 497 (2013)

Decay spectroscopy observables

Parity doublets

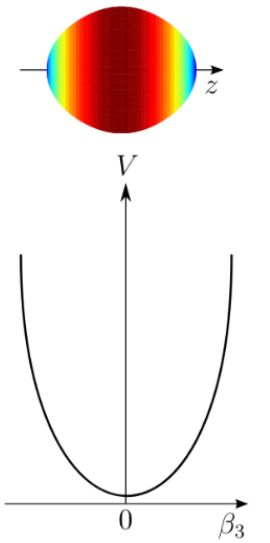
Soft octupole deformation

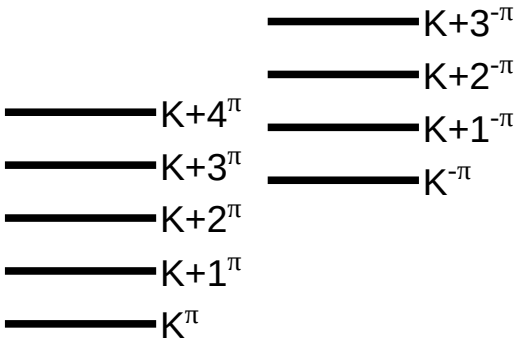




Splitting: 10s of keV

octupole vibration





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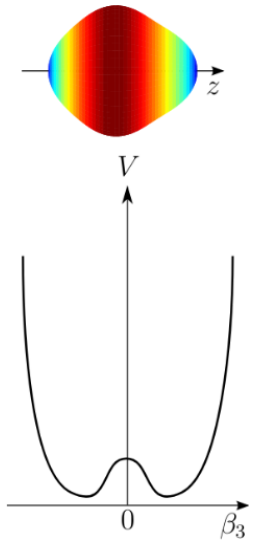

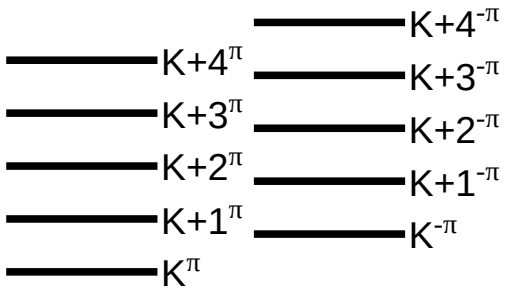

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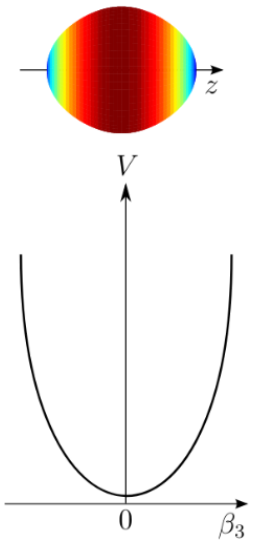

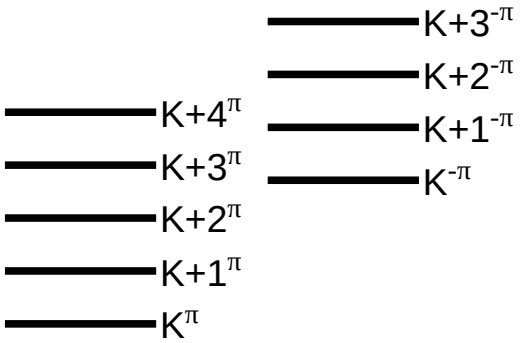

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Hindrance Factors

Hindrance factor: Empirical measurement of the **impact of structure effects on α-decay**

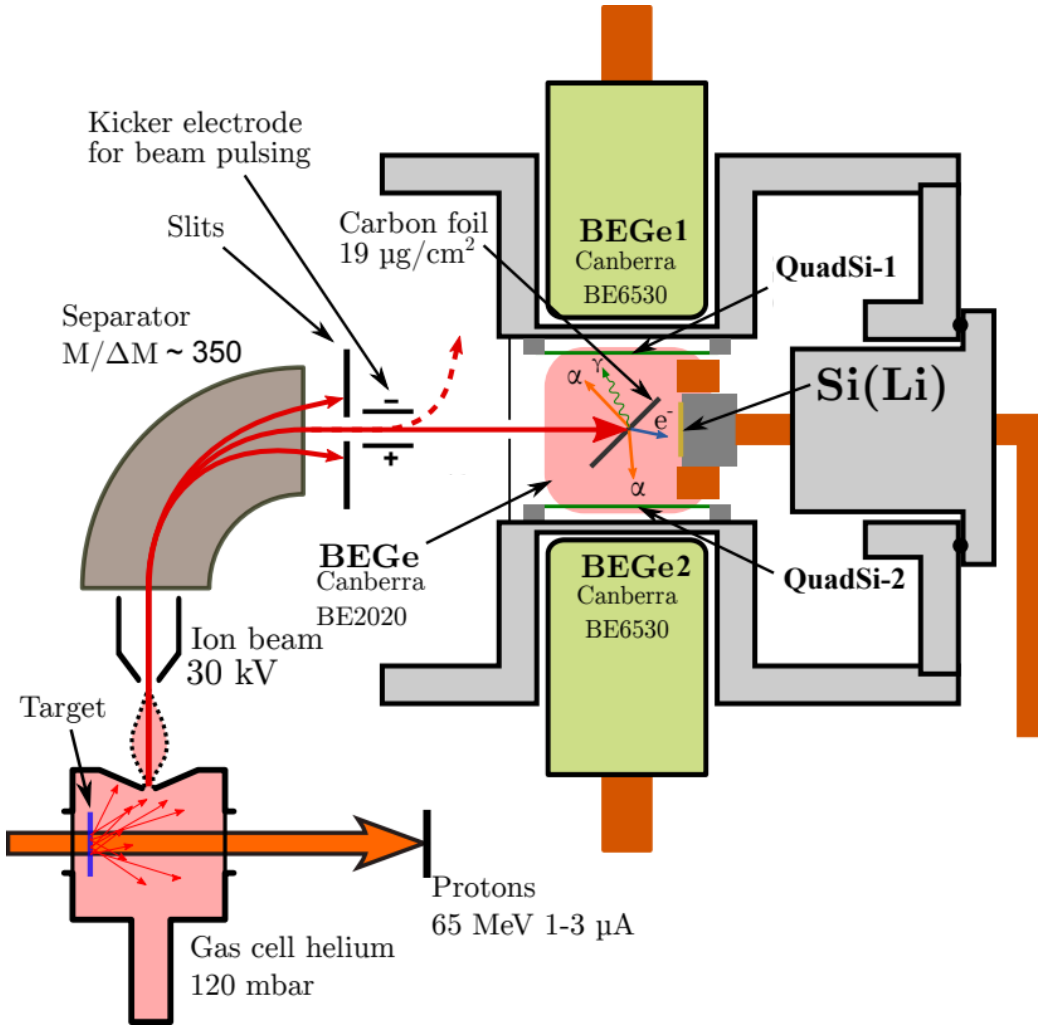
HF ~ 1-4: Identical initial and final single-particle states
HF ~ 4-10: Initial and final single-particle states are mixed/have a favourable overlap
HF ~ 10-100: Initial and final single-particle states do not have a favourable overlap, but have same parity and spin projection
HF ~ 100-1000: No favourable overlap, parity change, same spin projection
HF > 1000: No favourable overlap, parity change, spin flip

Alpha-decay tends to conserve parity and parity change will produce large (>100) hindrance factors

However: **Octupole deformation breaks parity**

Alpha-decay towards opposite parity states becomes more favoured (HF~10)

The I262 experiment @IGISOL (Jyväskylä)



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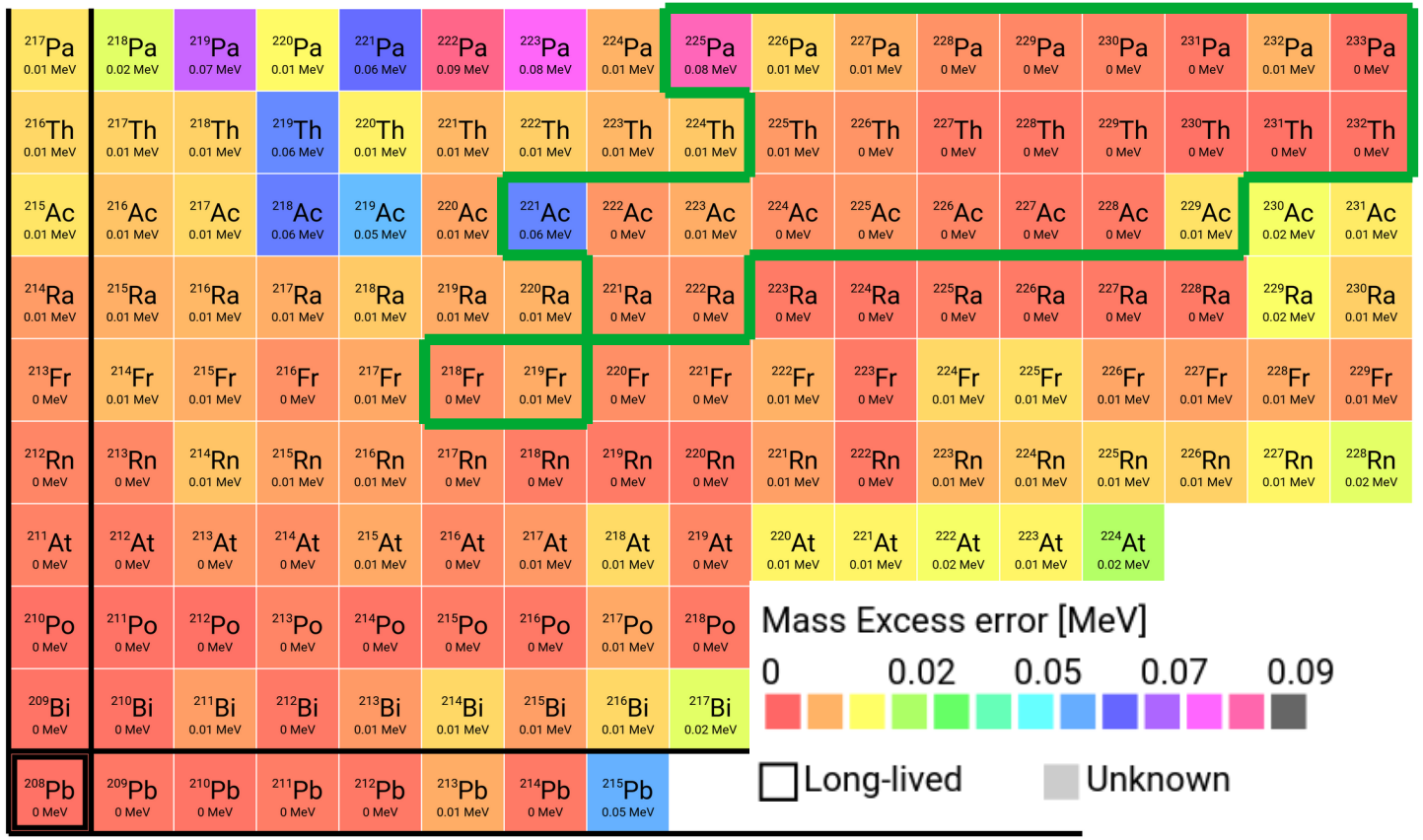

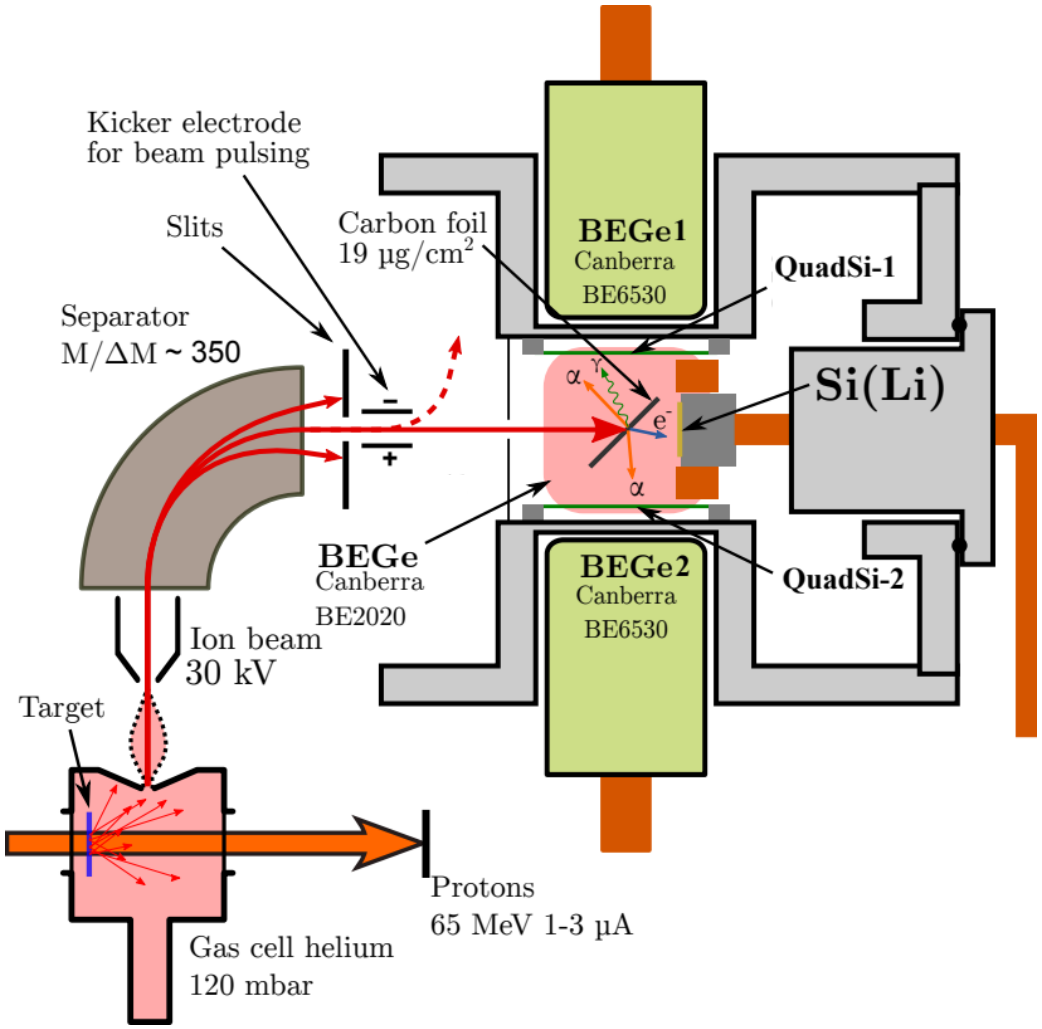

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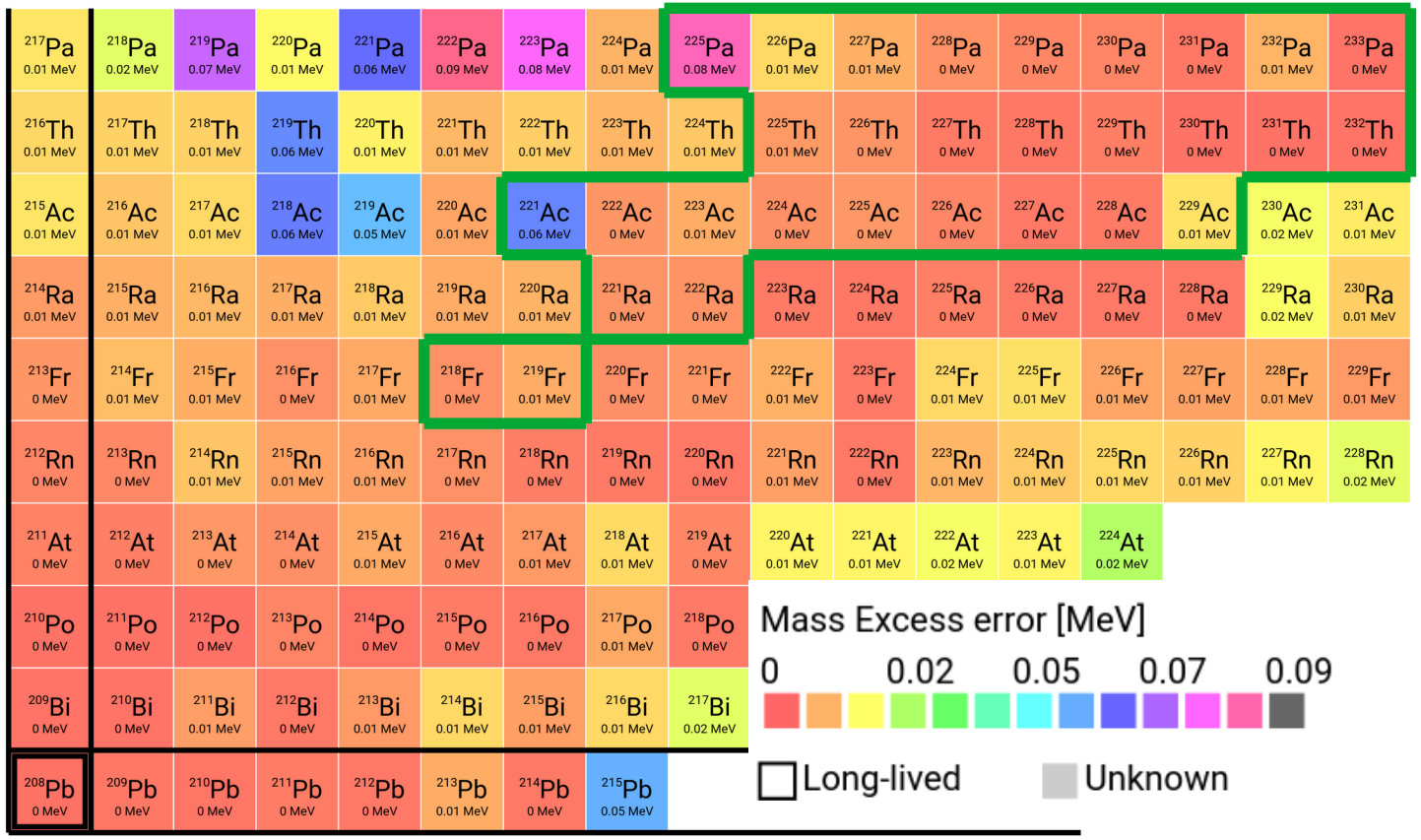


Analysis

$^{225}Pa \rightarrow {}^{221}Ac \rightarrow {}^{217}Fr$

Literature :

	E_α(keV)	I(%)
^{225}Pa	7170(5)	17(1)
	7235(5)	30(2)
	7261(5)	53(2)

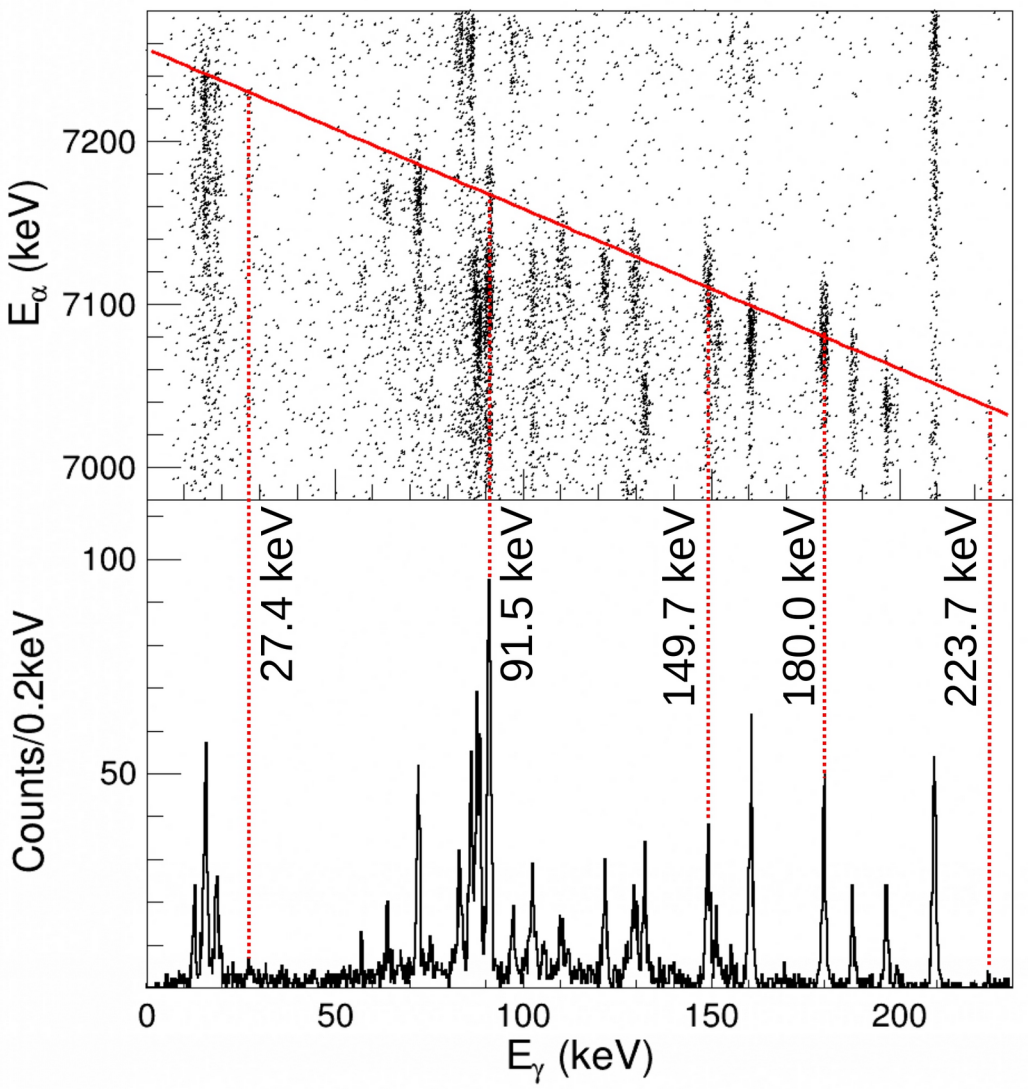
(1988) Nuclear Inst. and Methods in Physics Research, B, 31 (3), pp. 483-486

Data analysis

$$Q_\alpha(\text{g.s.-to-g.s.}) = Q_\alpha + E_\gamma$$

$$Q_\alpha = \frac{m_d + m_\alpha}{m_d} \times E_\alpha$$

$$E_\alpha = E_\alpha(\text{g.s.-to-g.s.}) - \frac{m_d}{m_d + m_\alpha} E_\gamma$$



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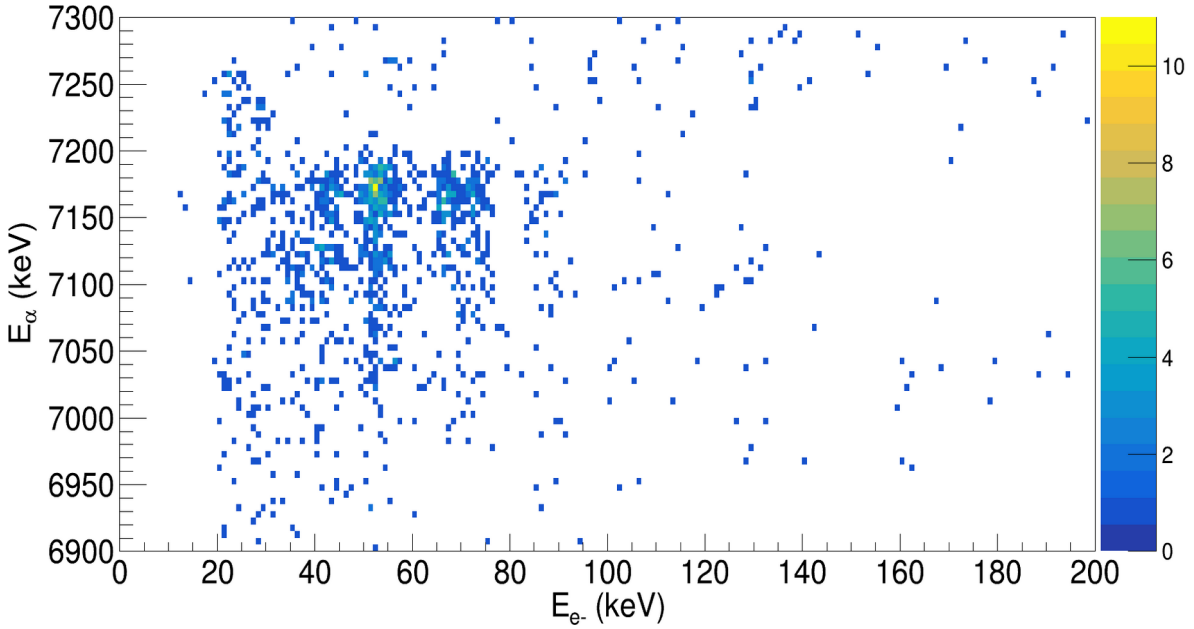

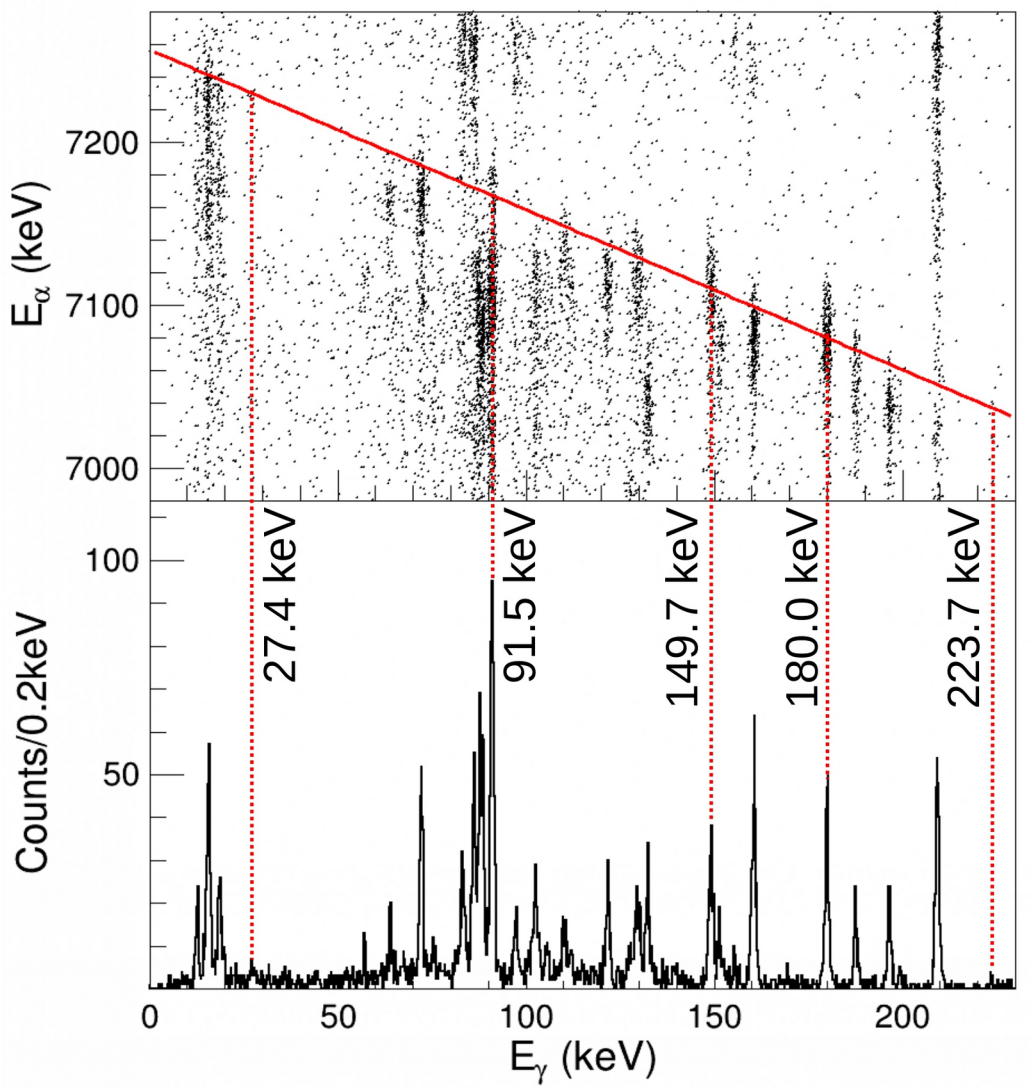

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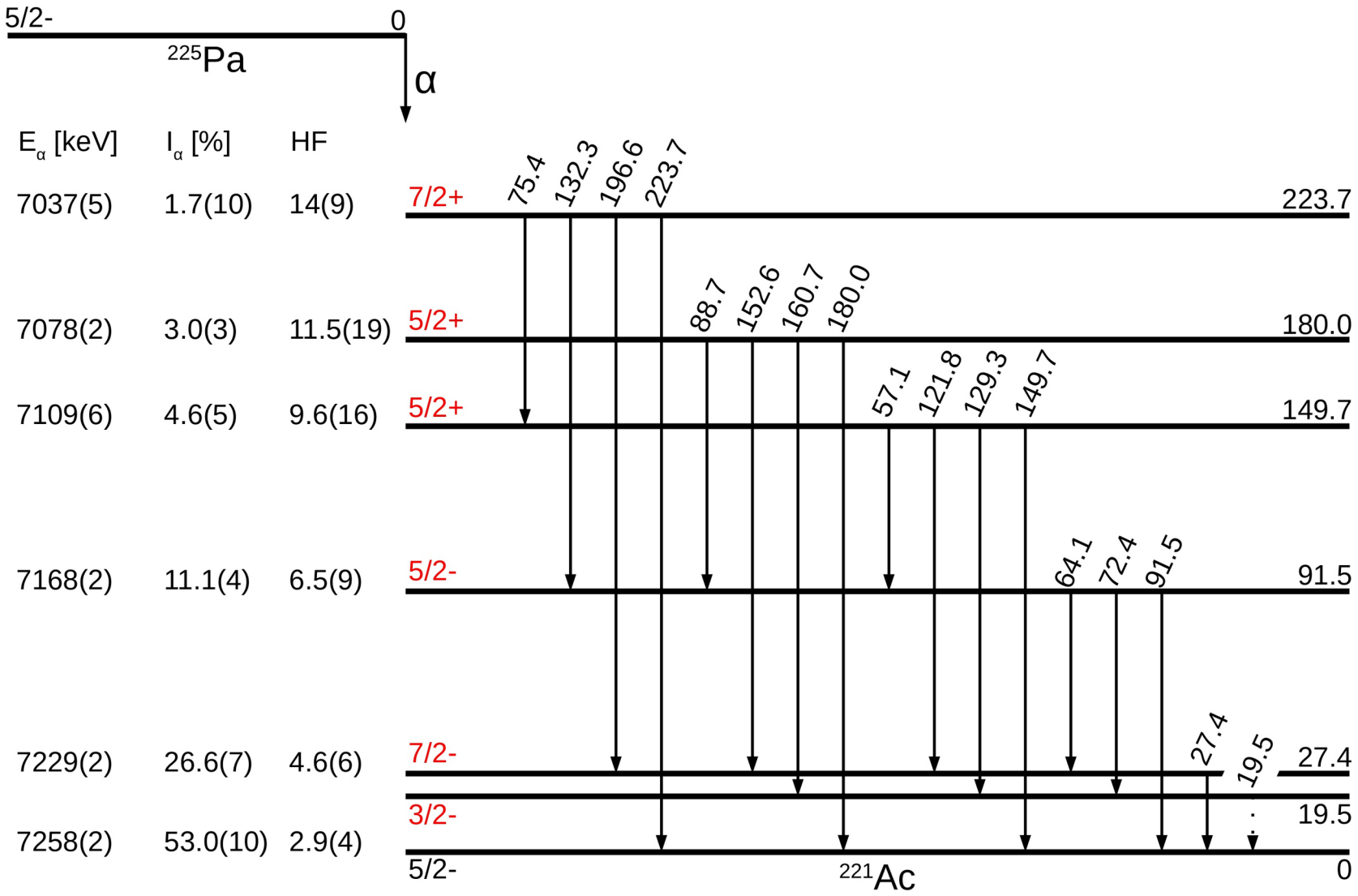

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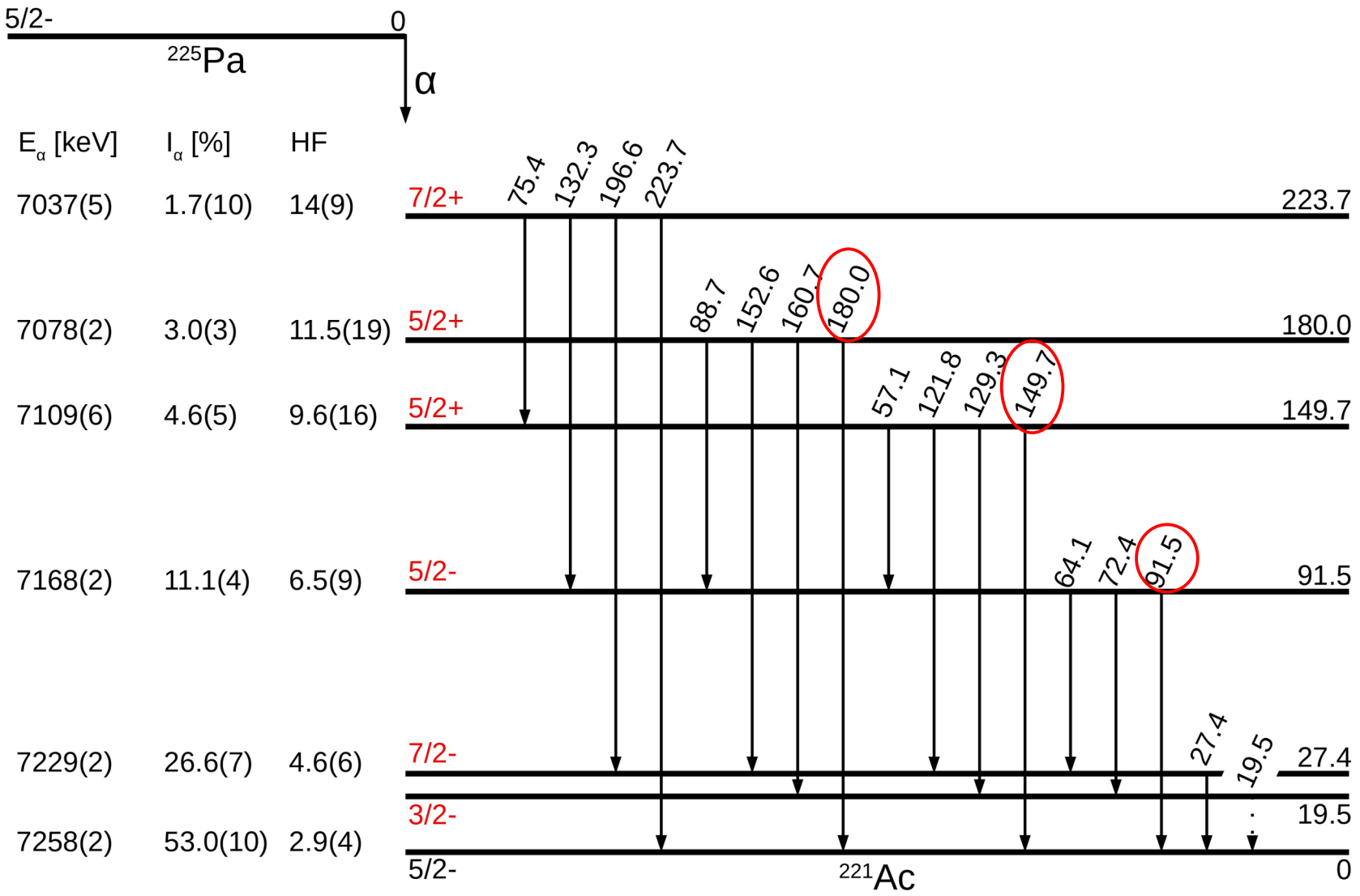
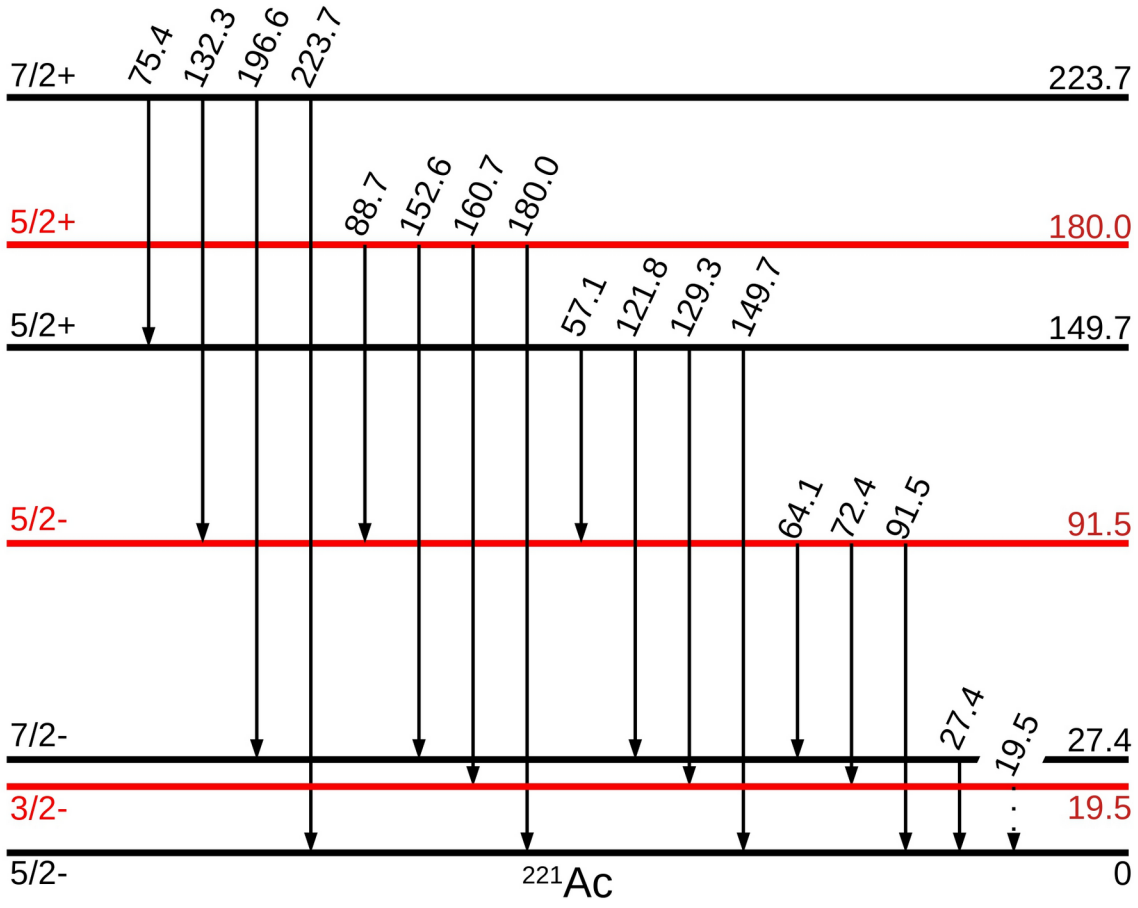


Interpretation



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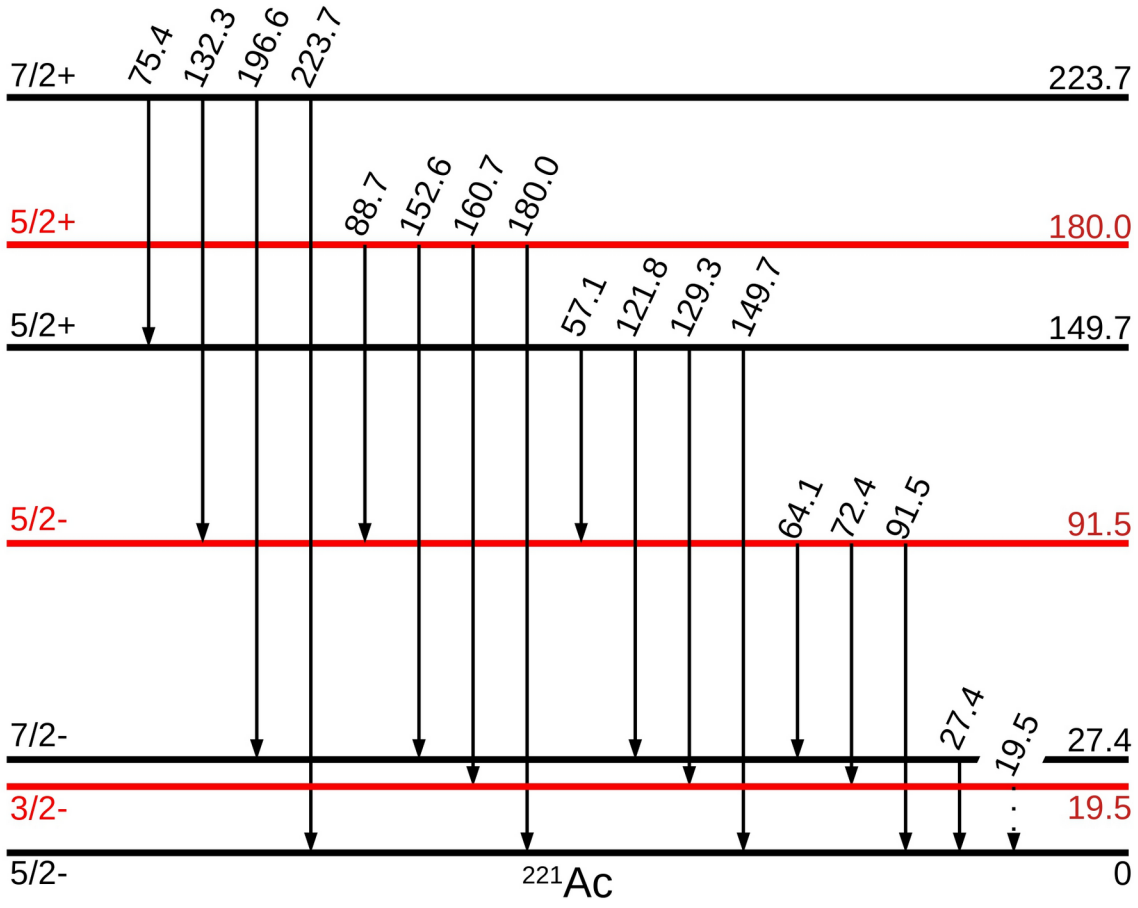
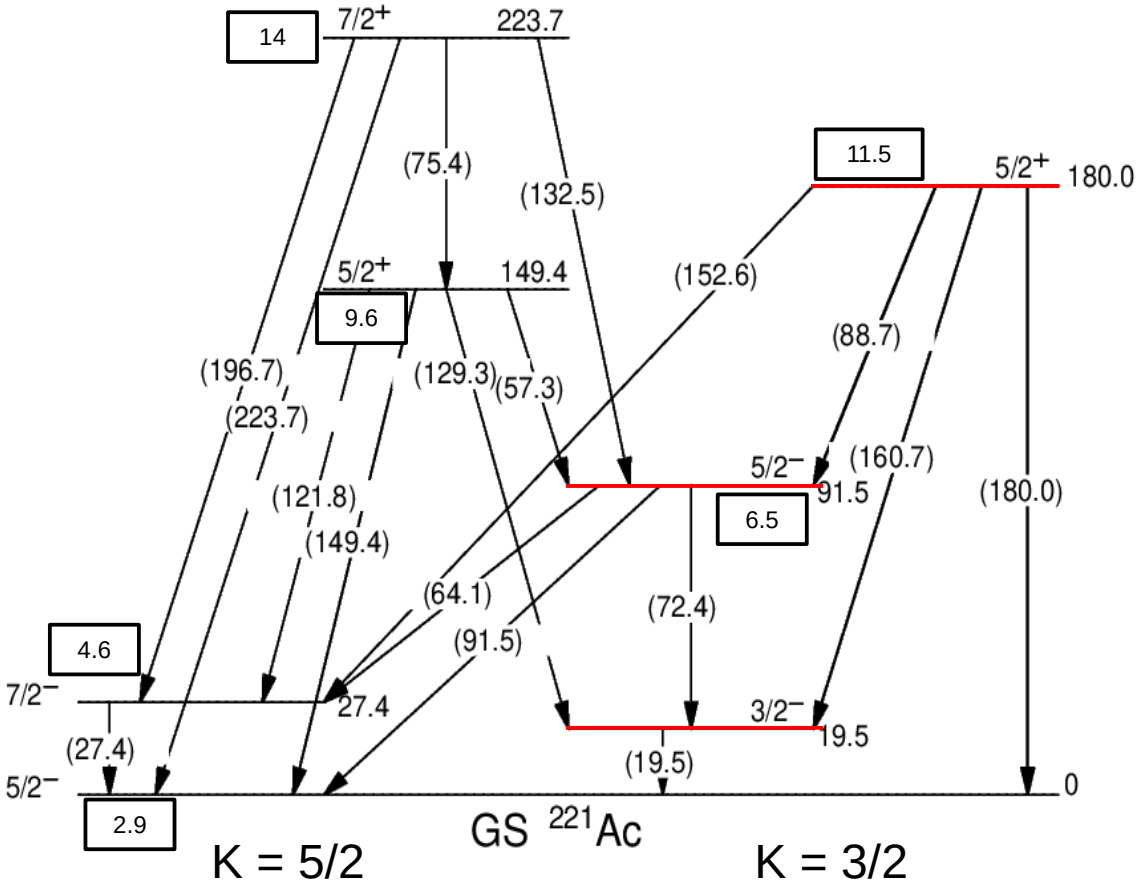


^{225}Pa Ground state: 5/2$^-$



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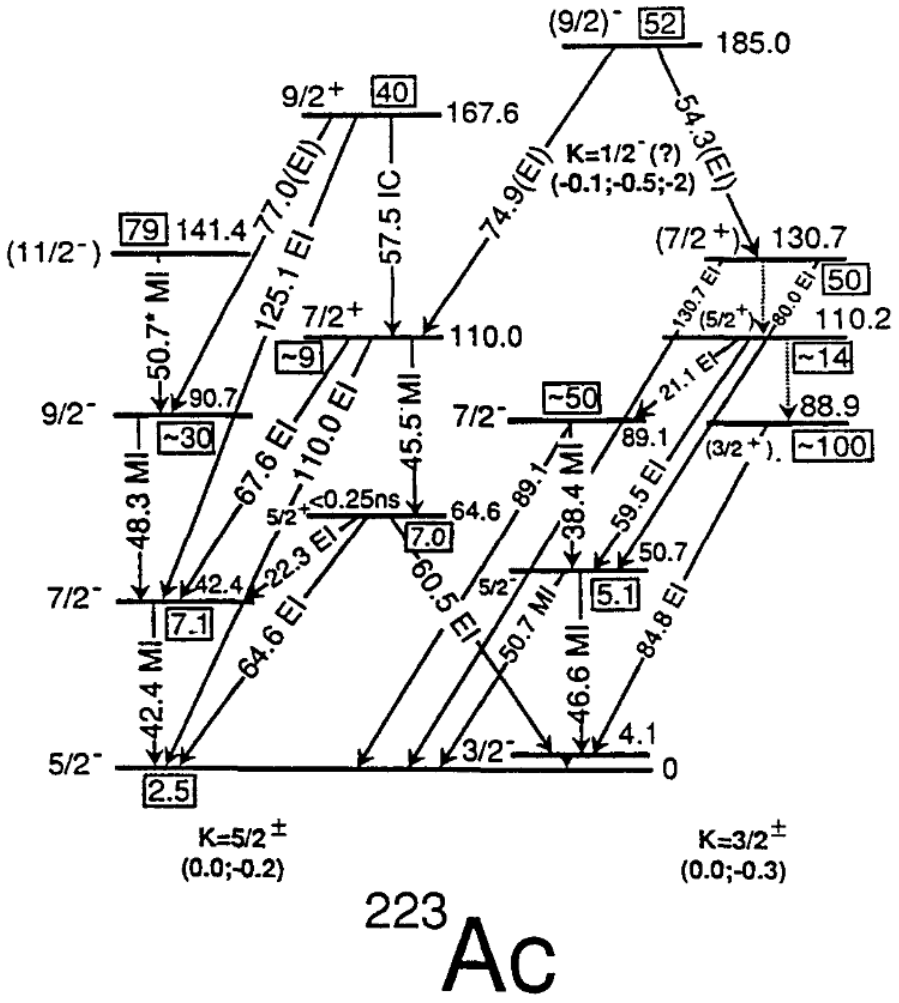

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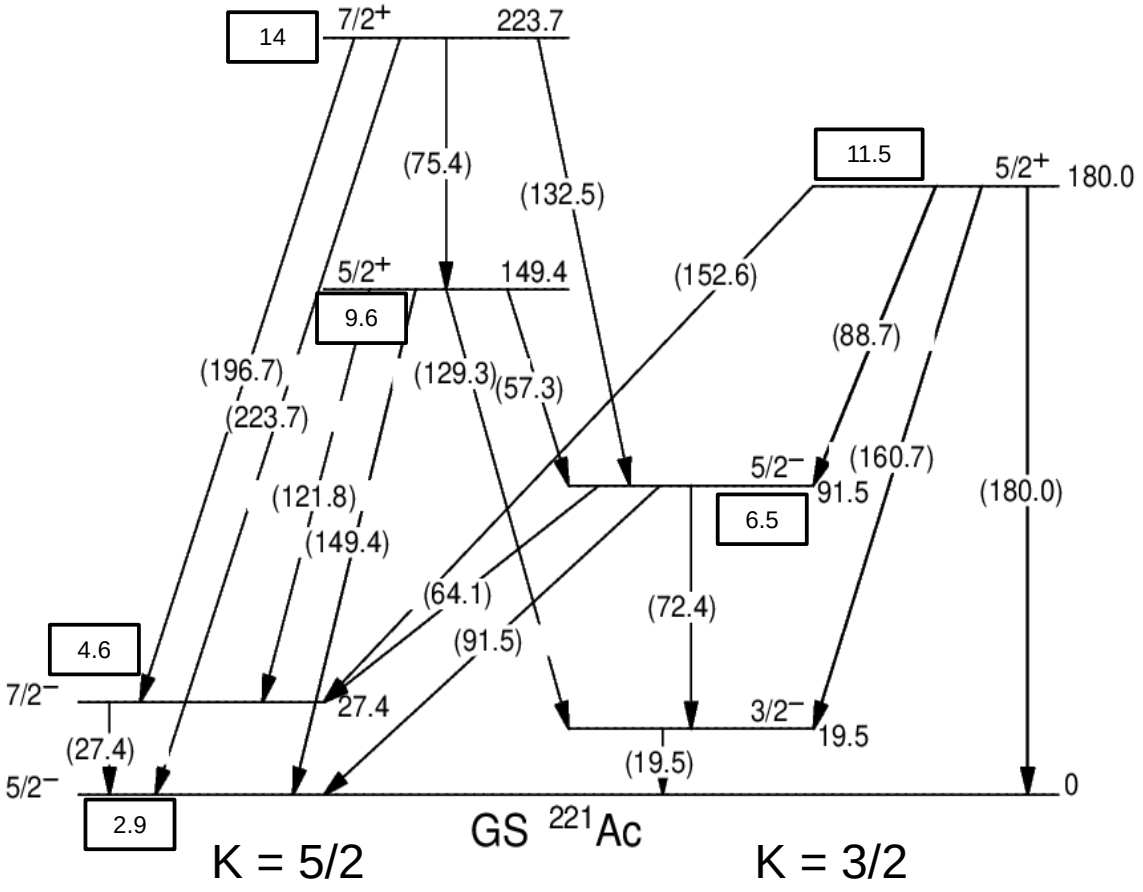

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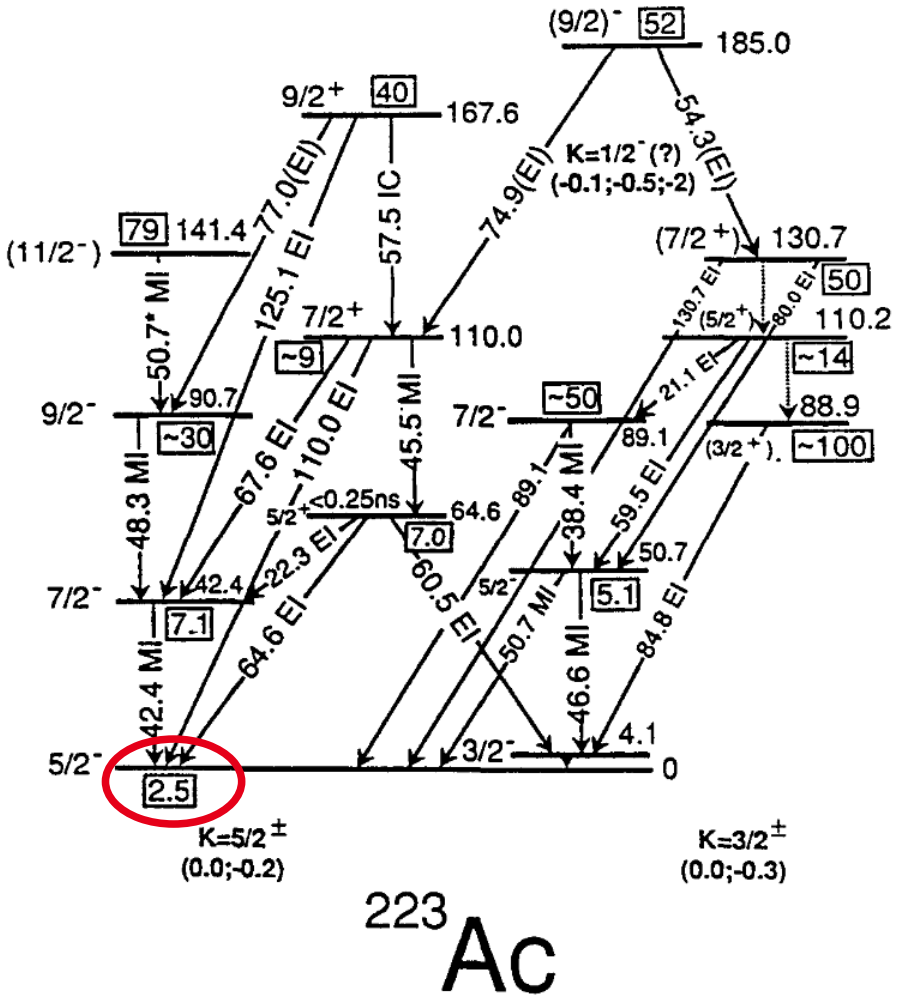

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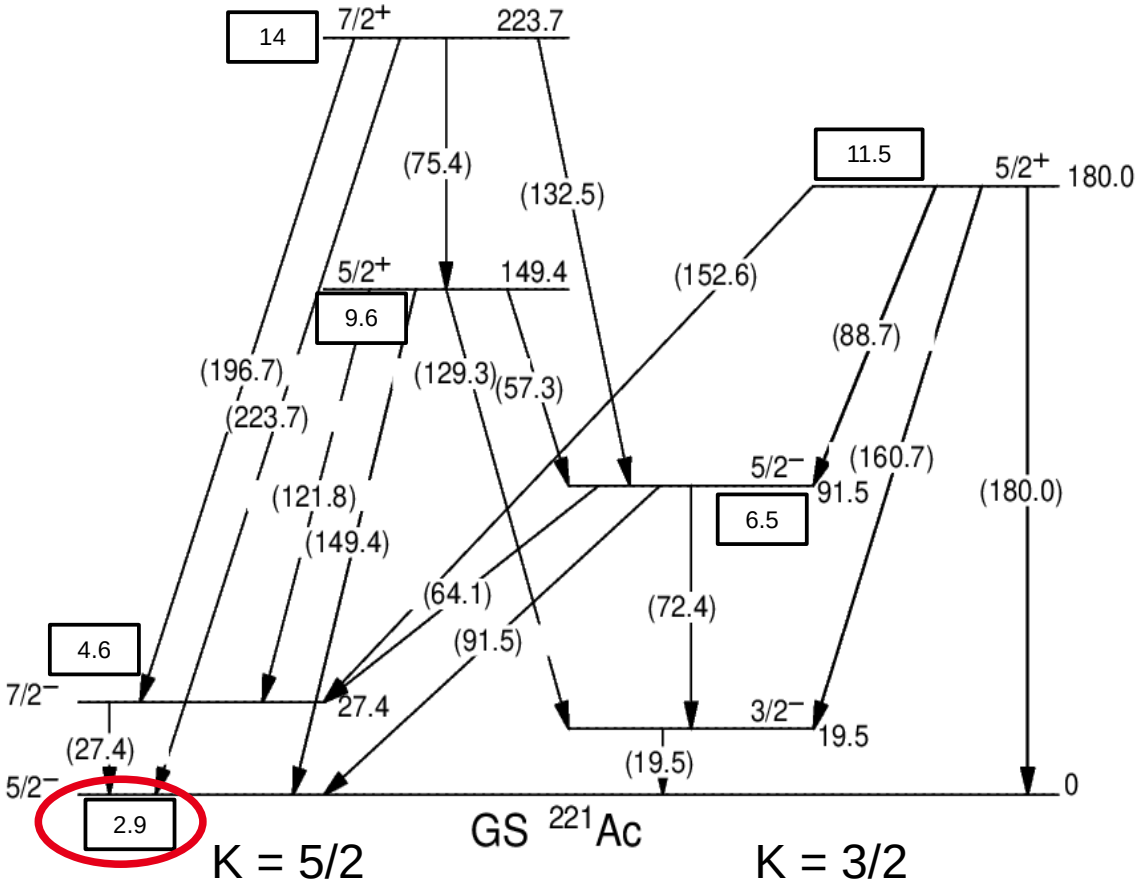

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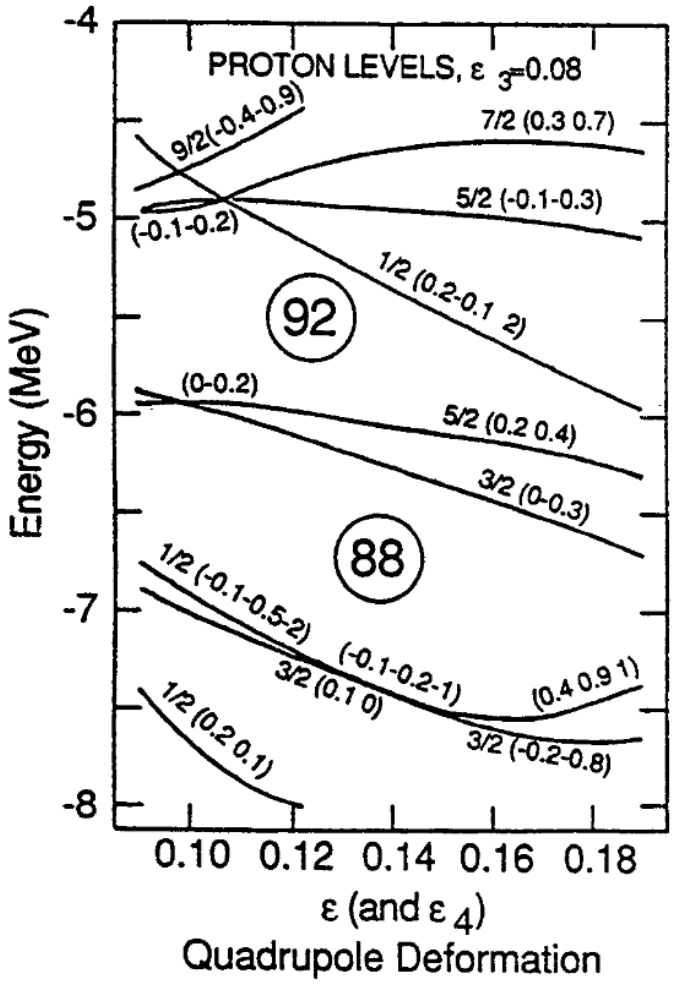

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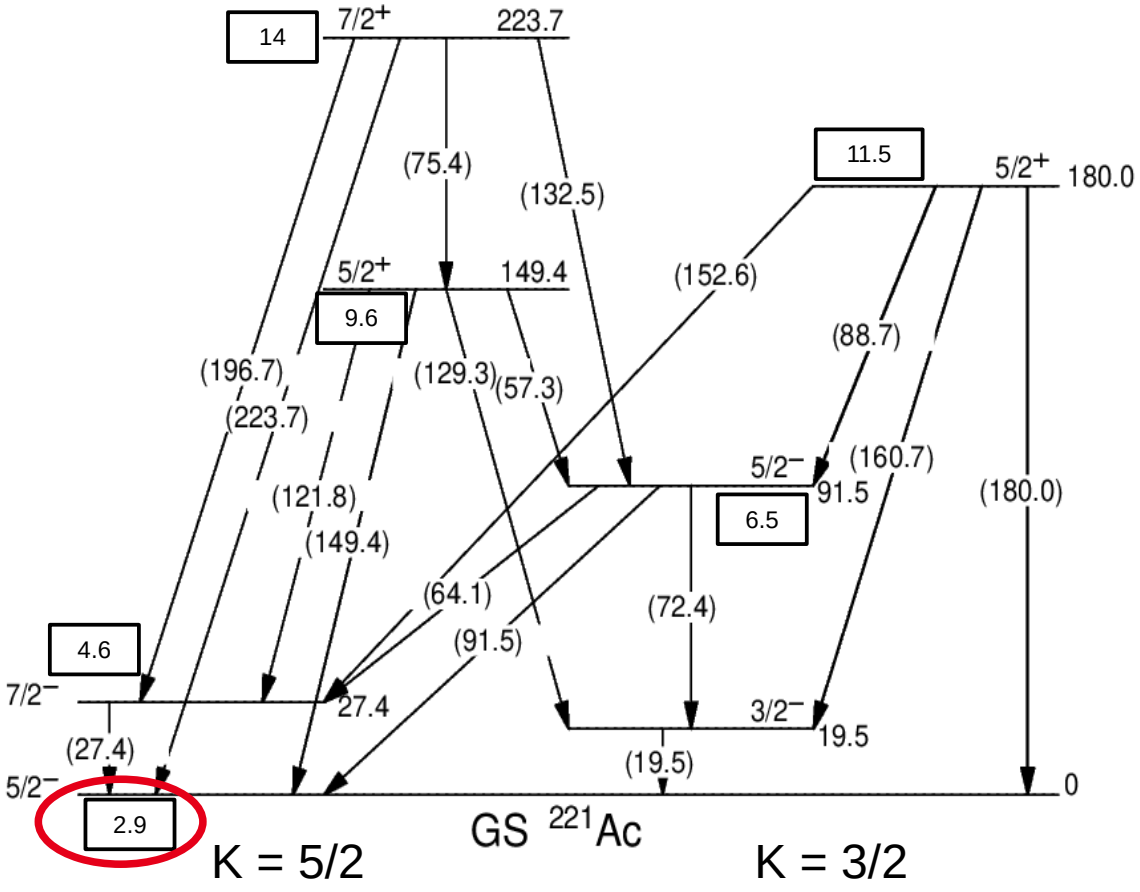

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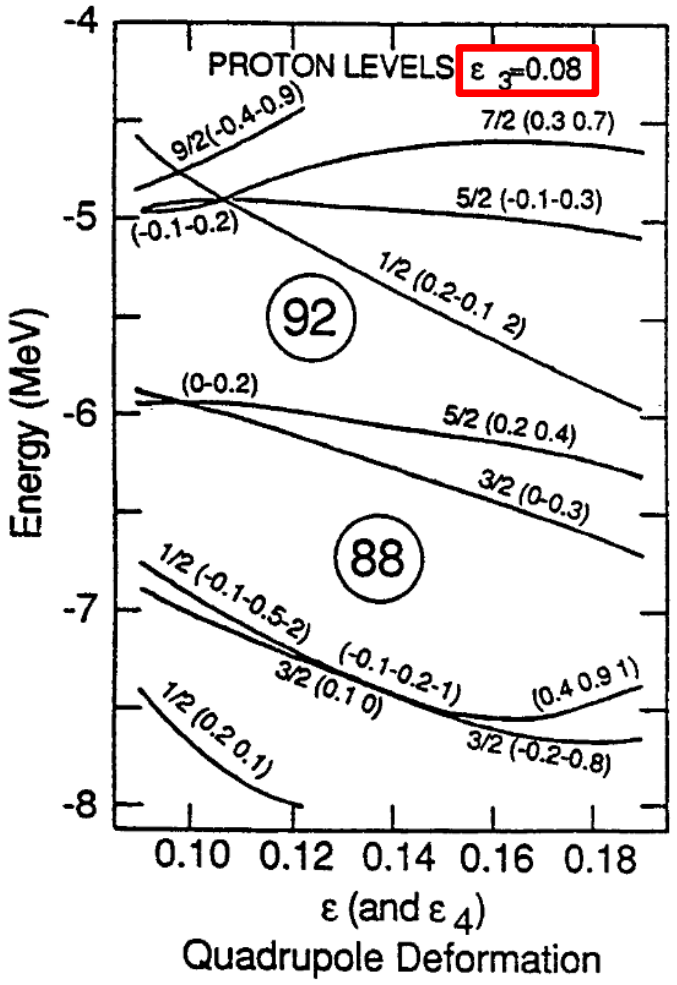

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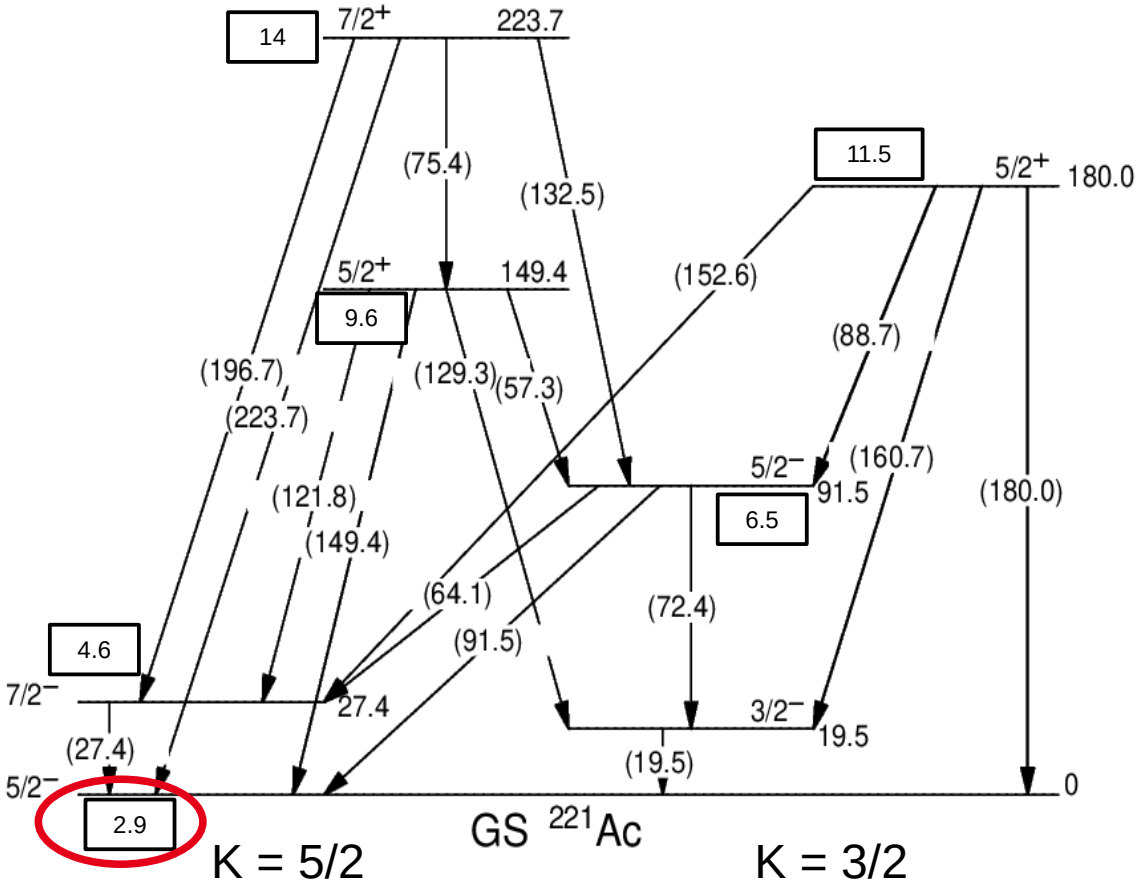

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Ac: Z=89
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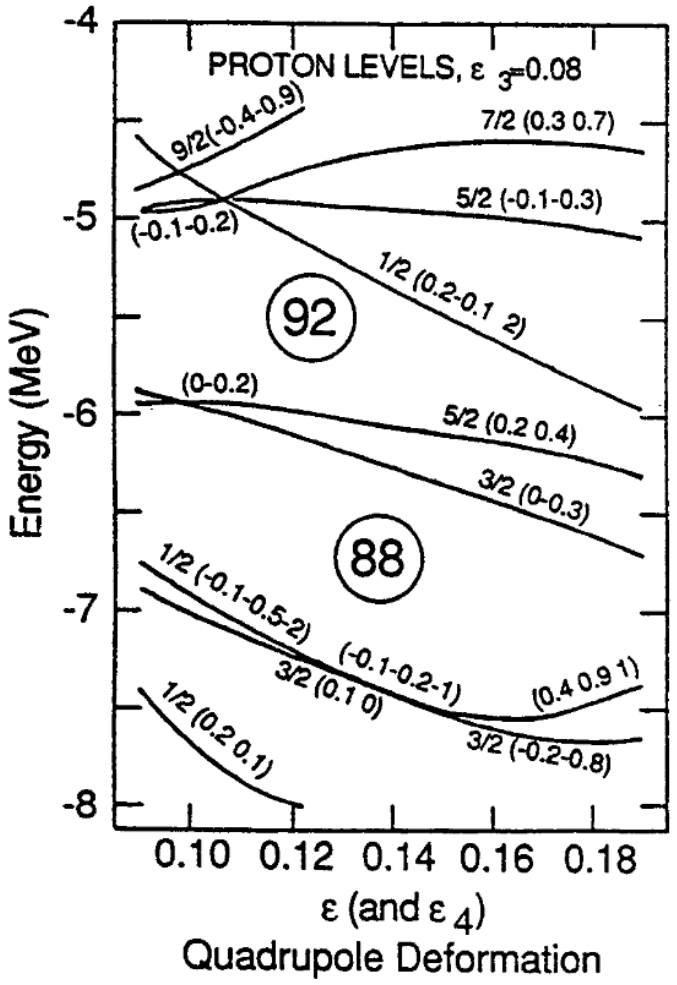

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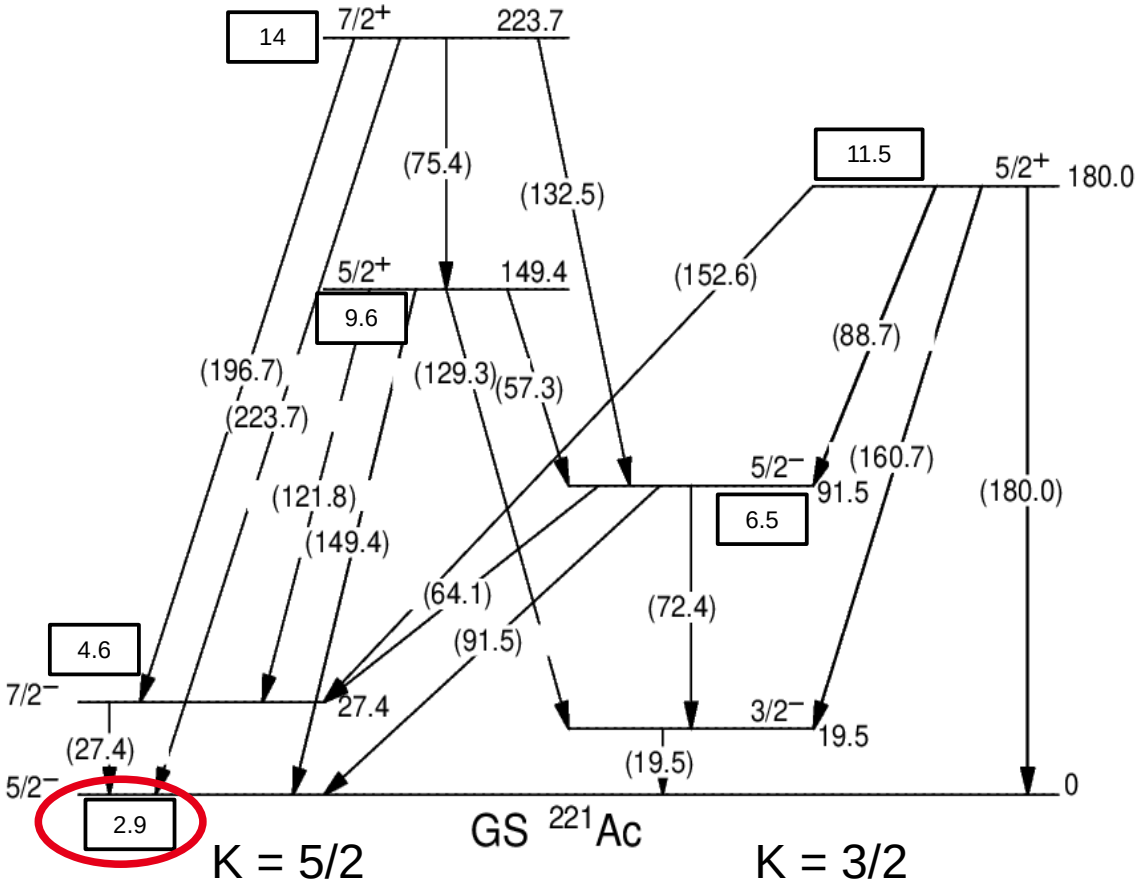

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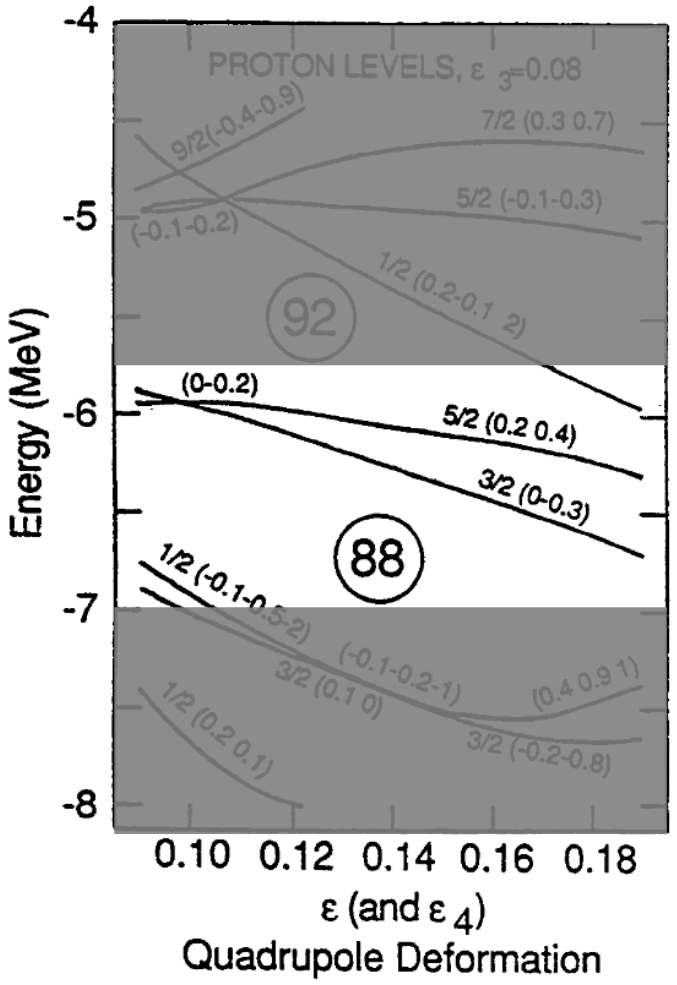

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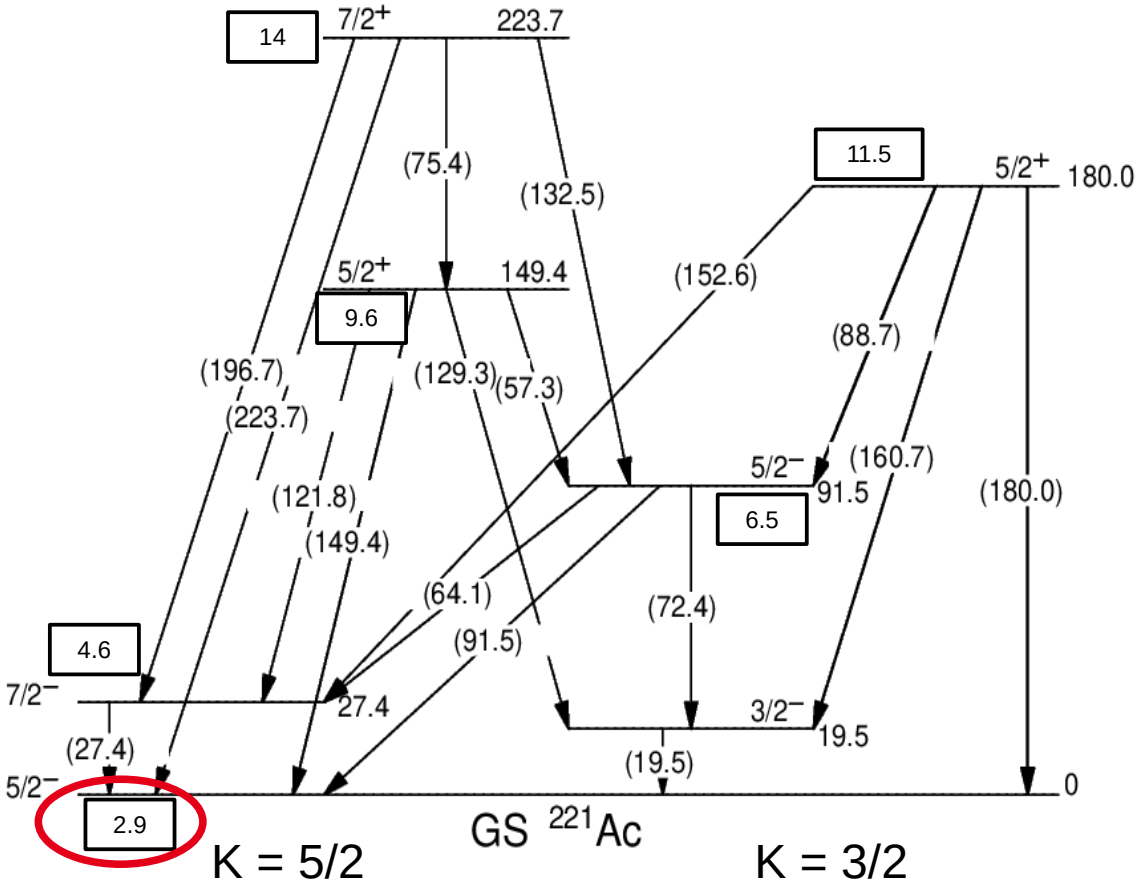

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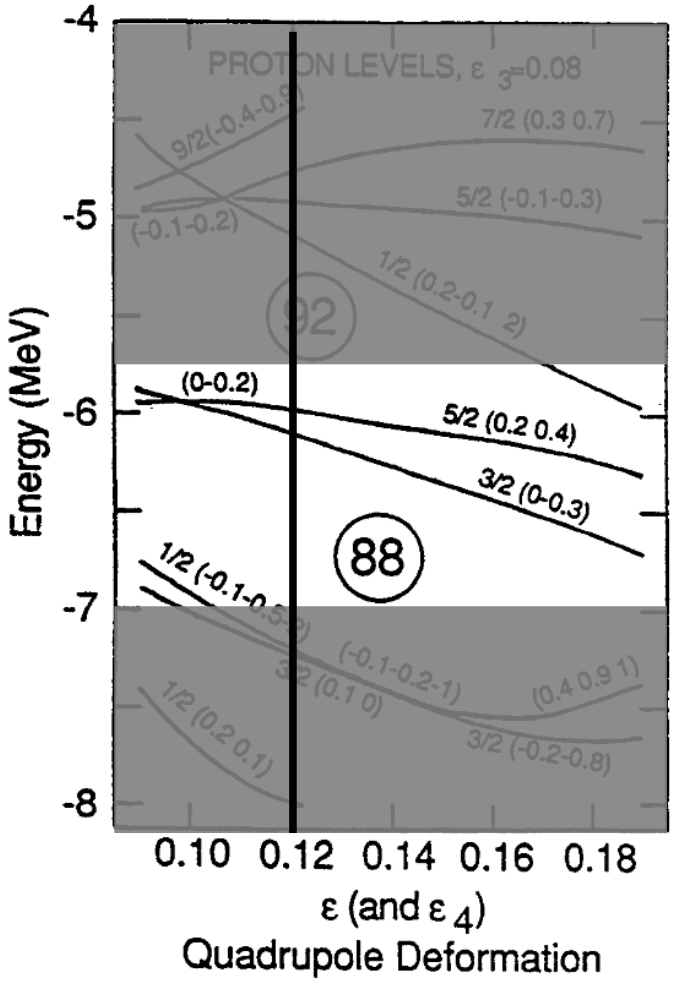

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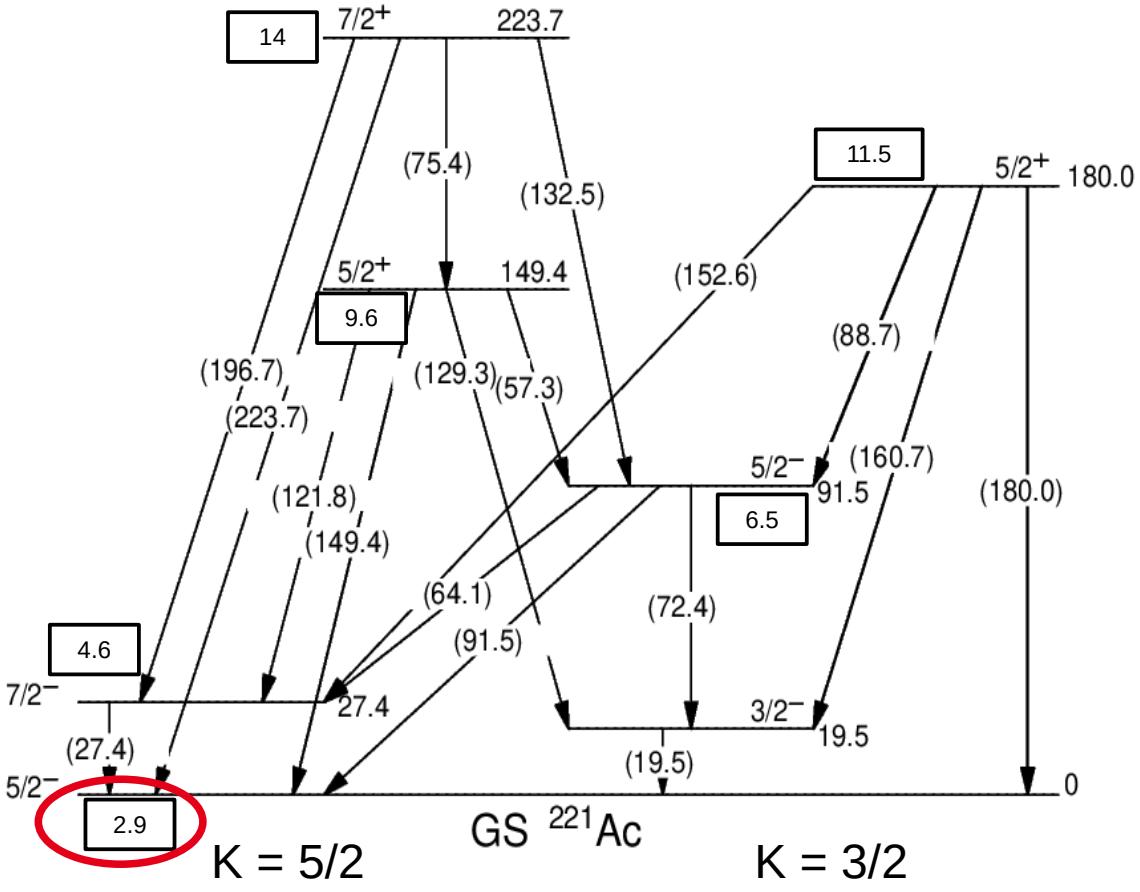

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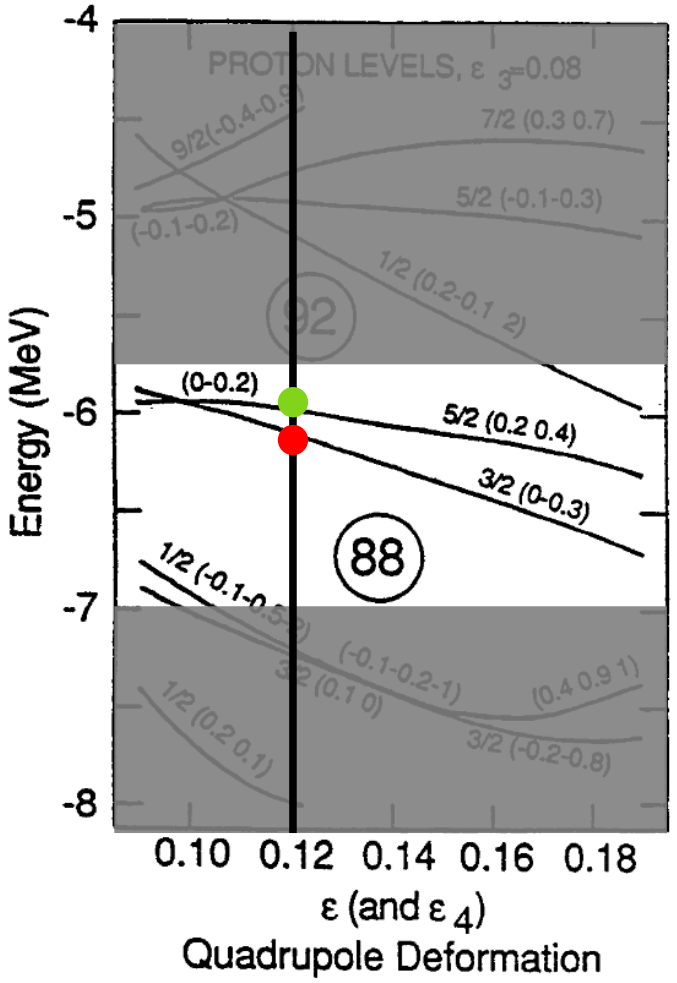

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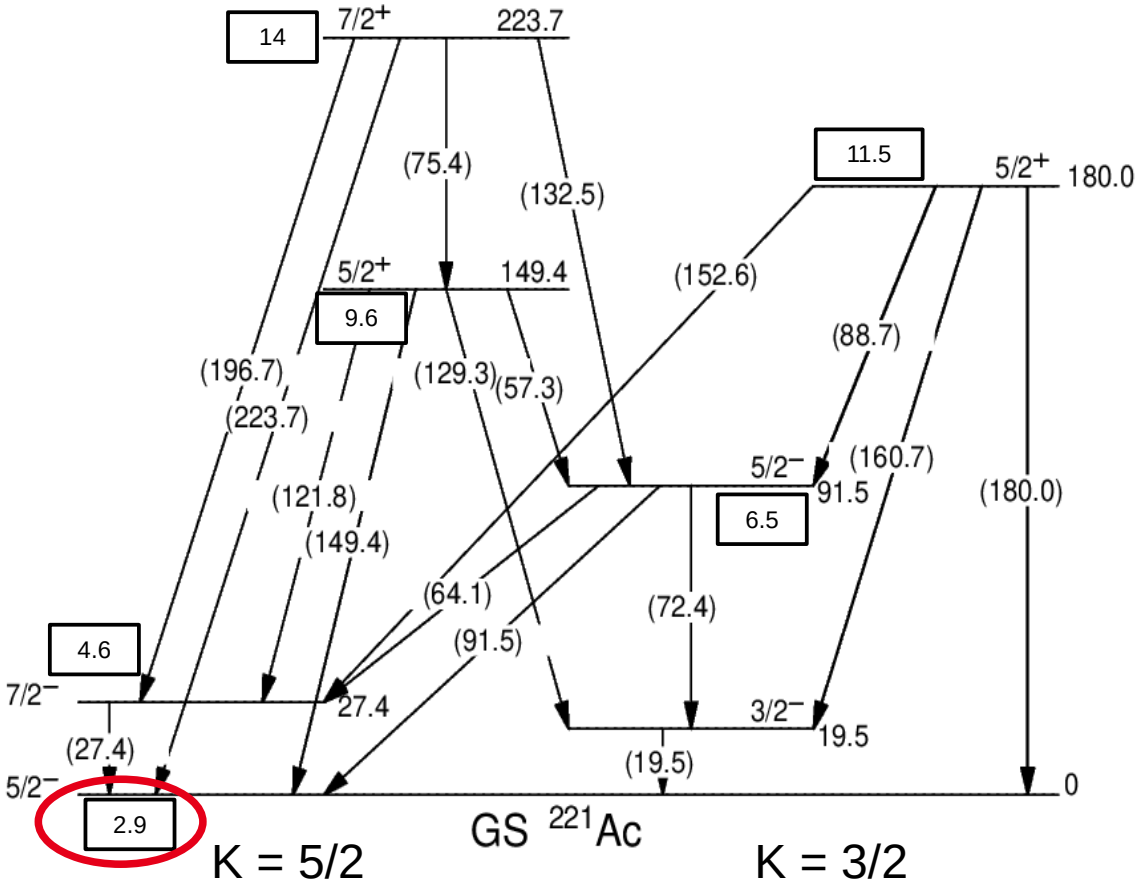

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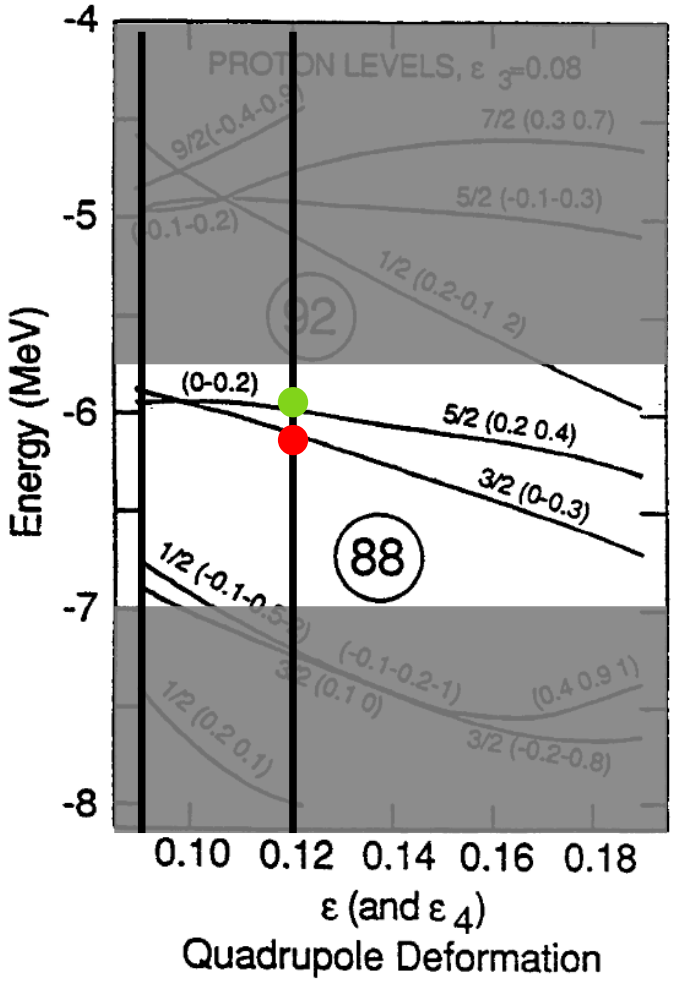

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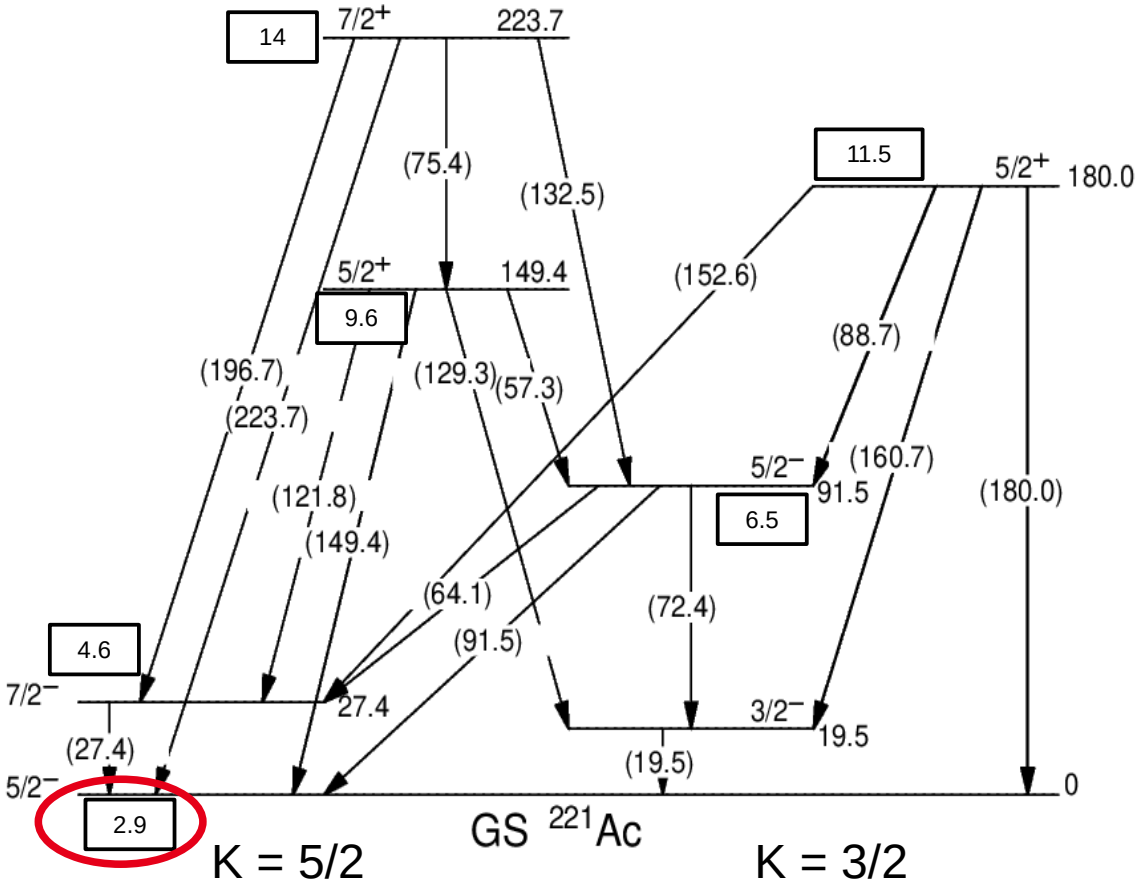

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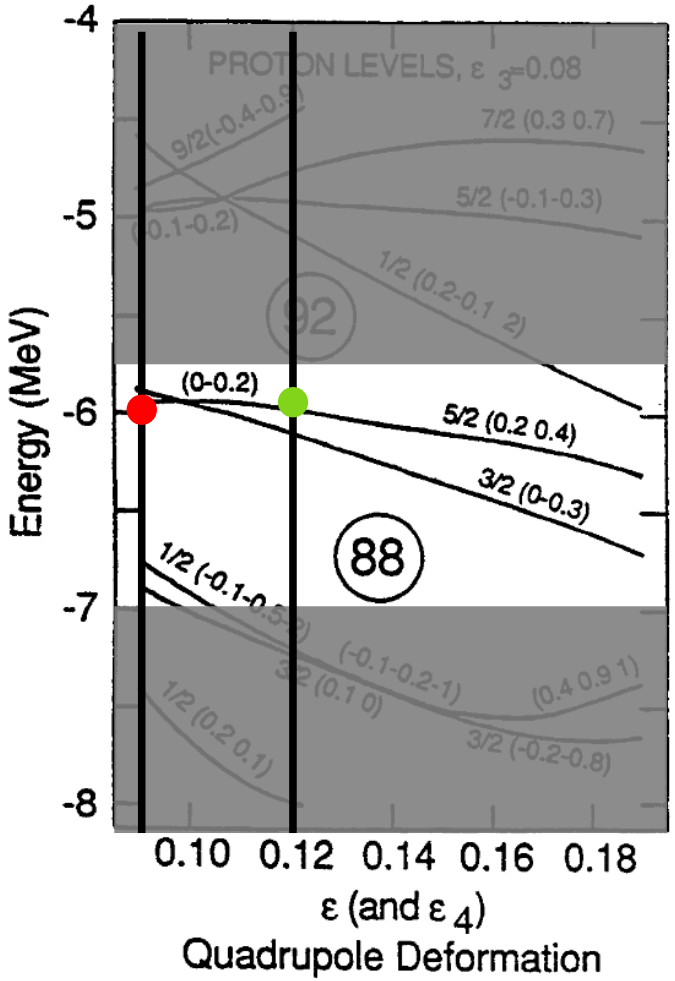

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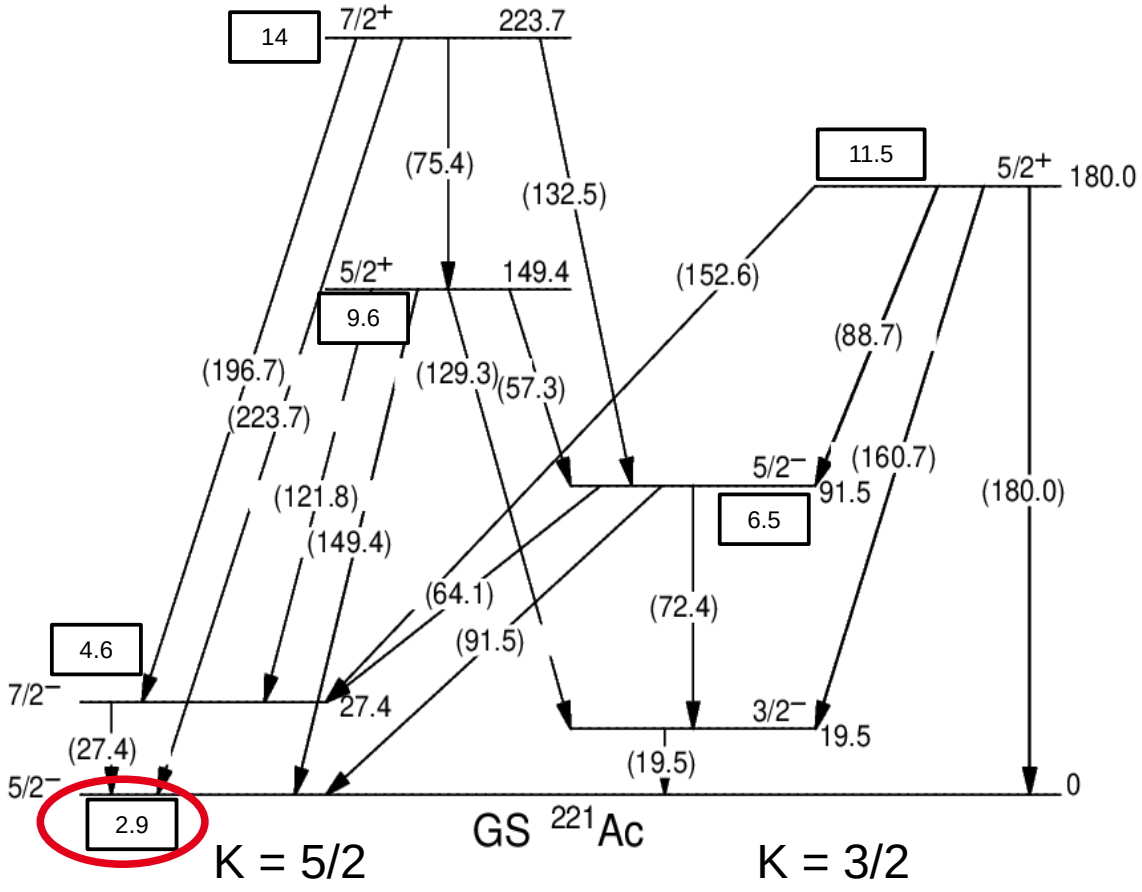
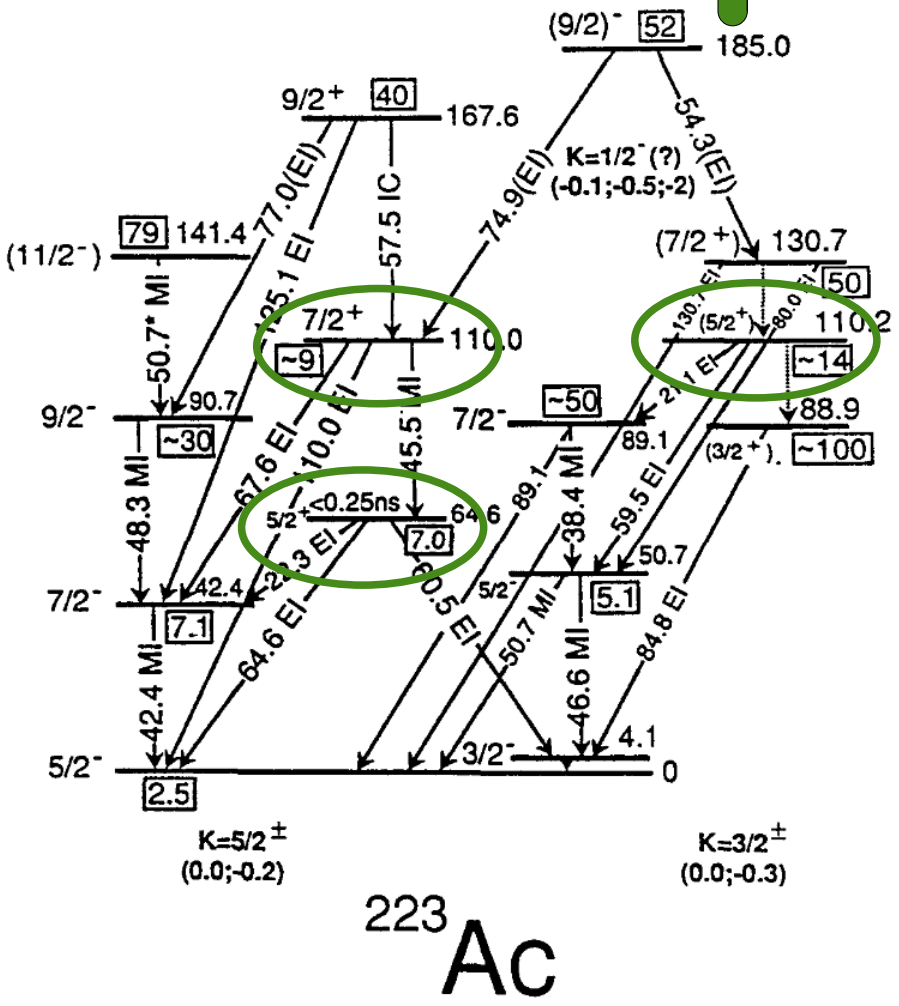
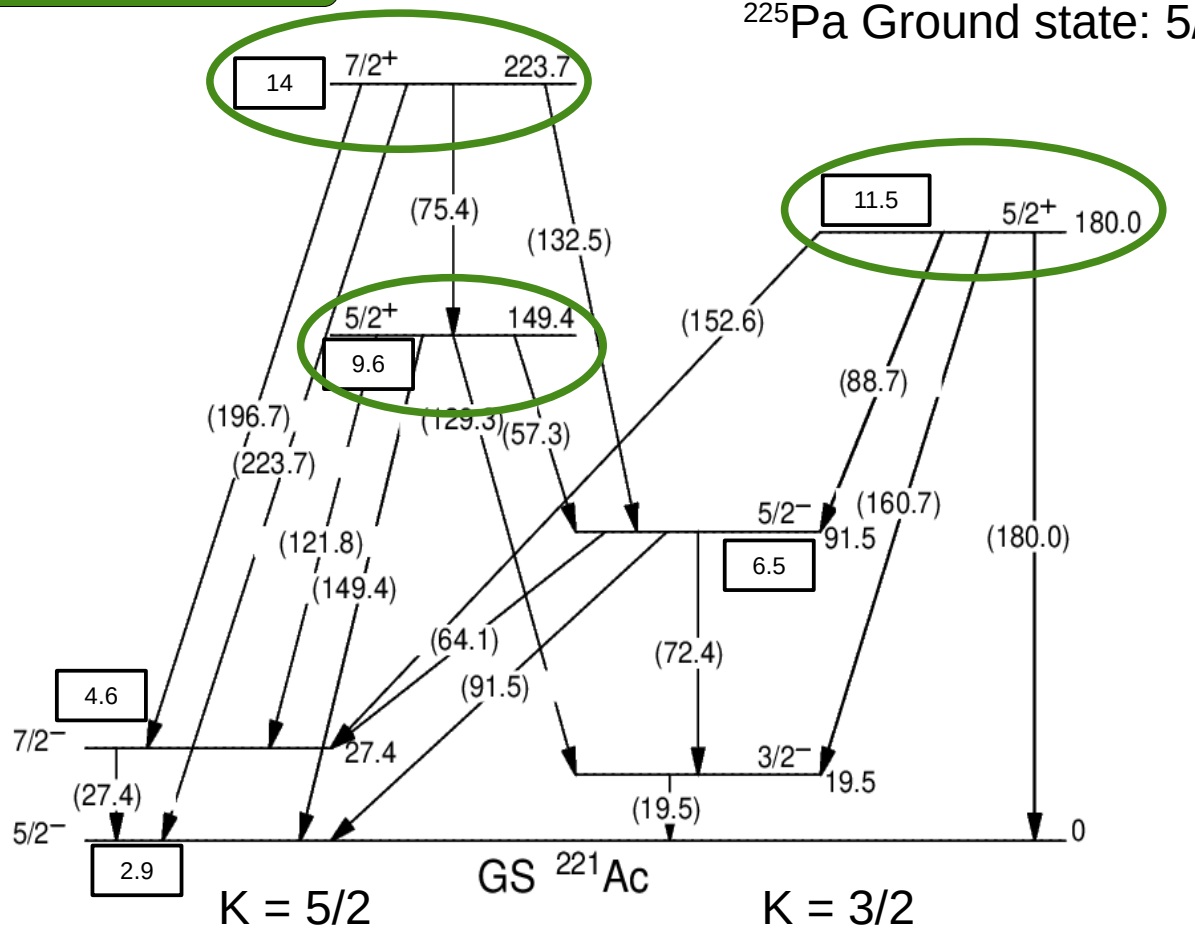


Interpretation

Hindrance Factors





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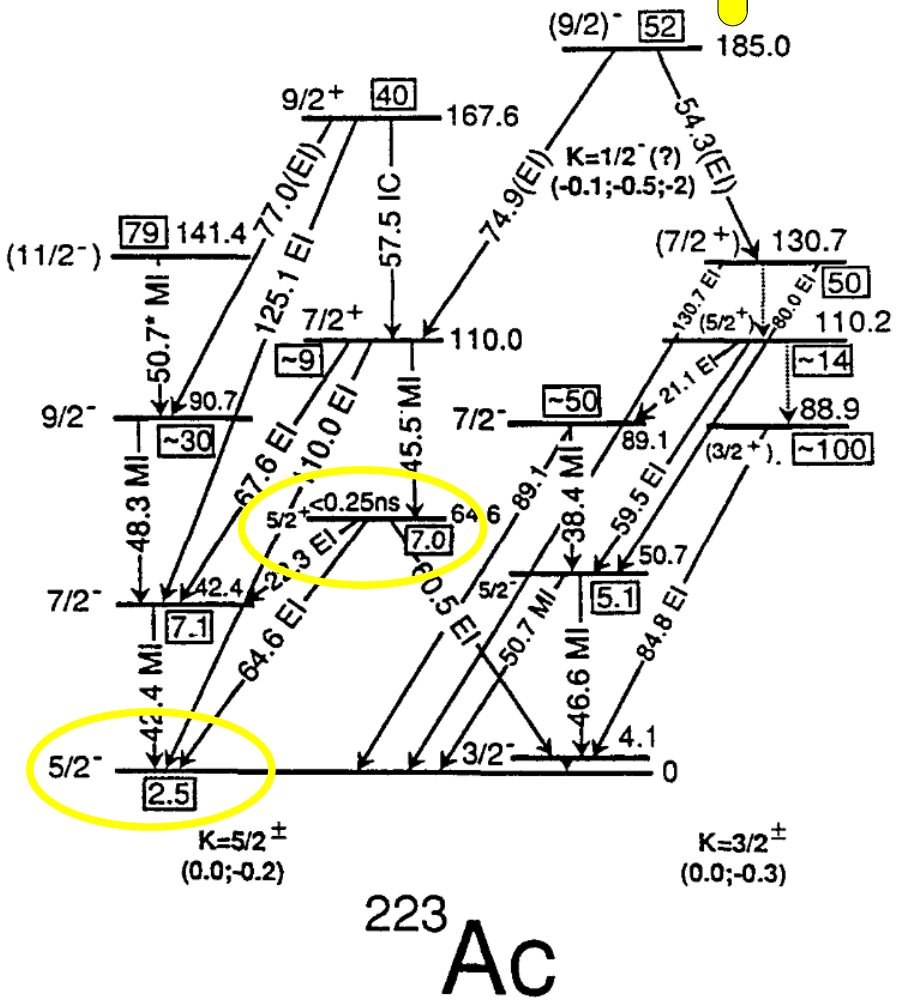
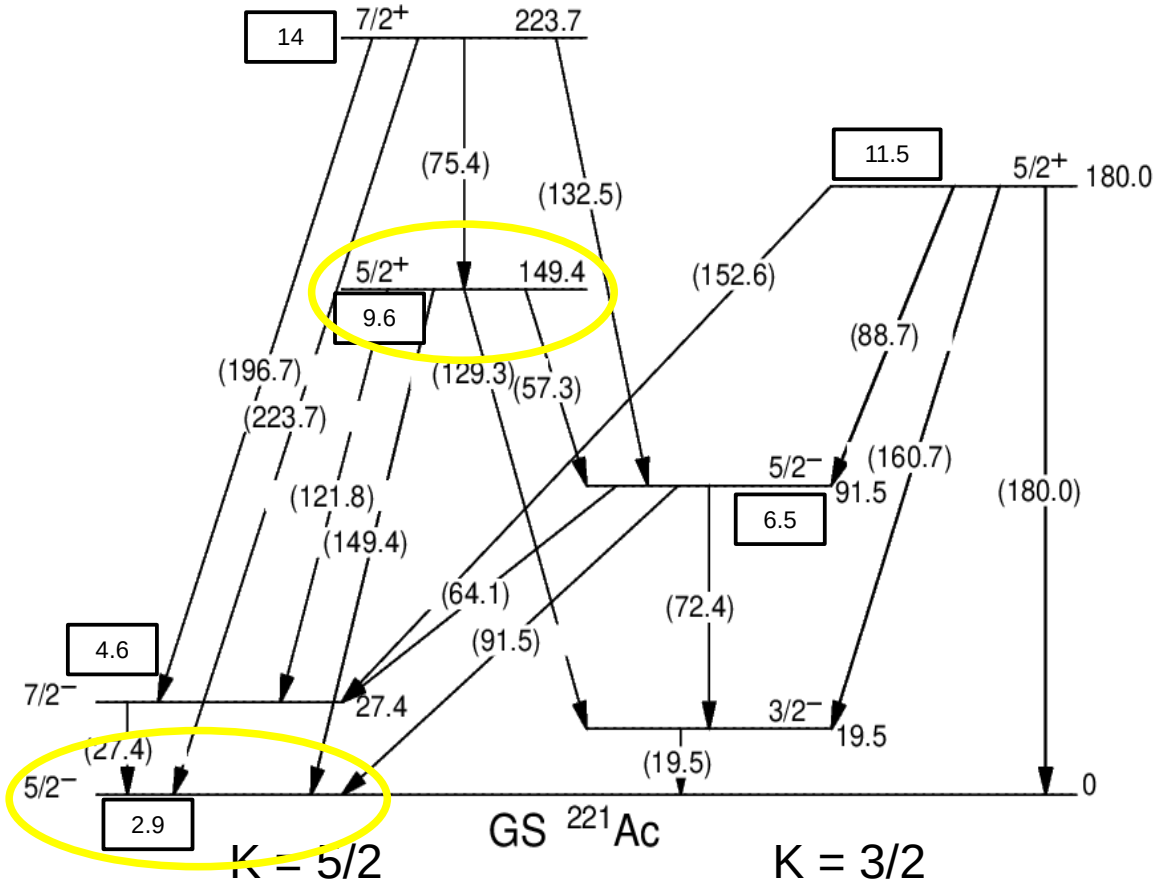
Interpretation

Parity doublets





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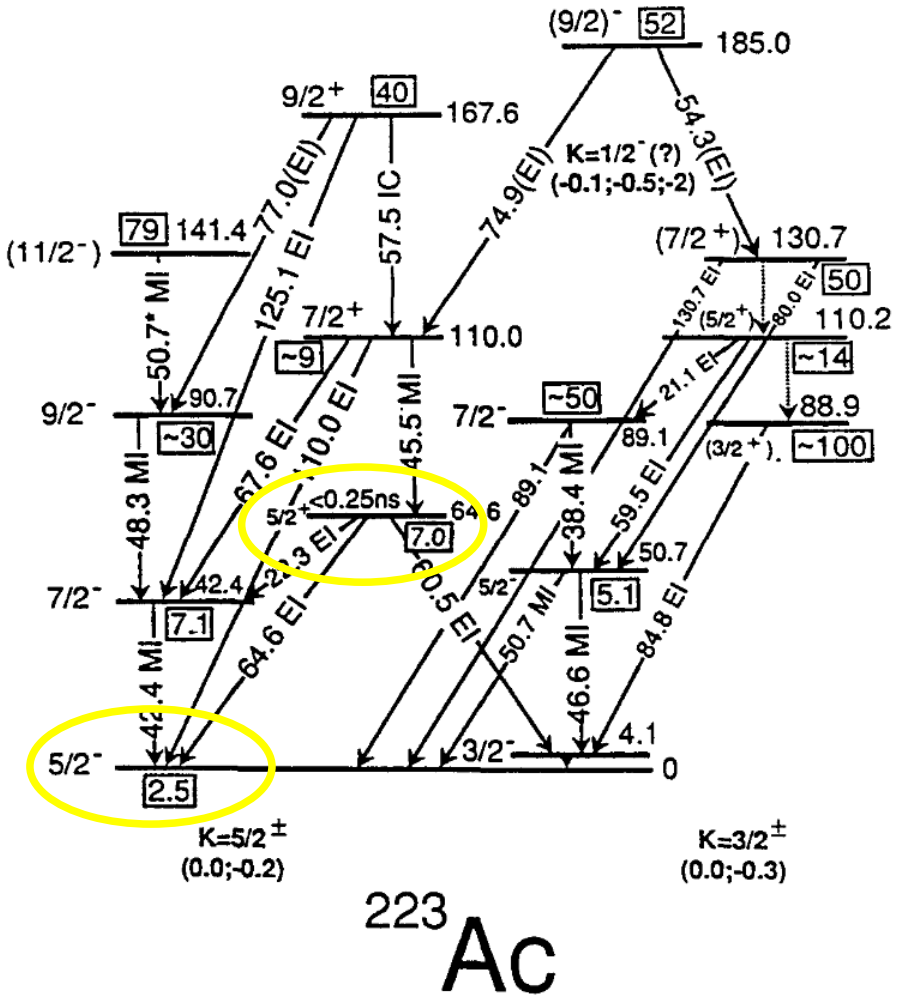

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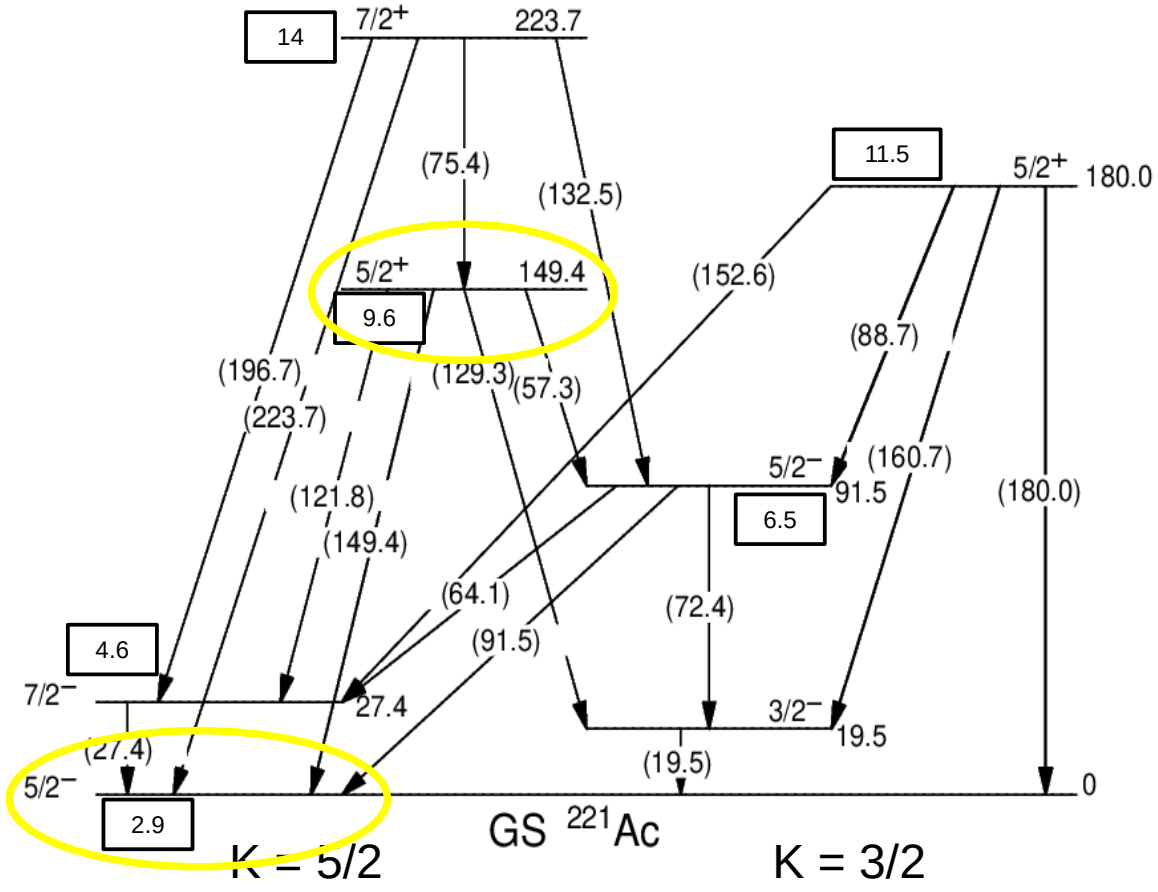
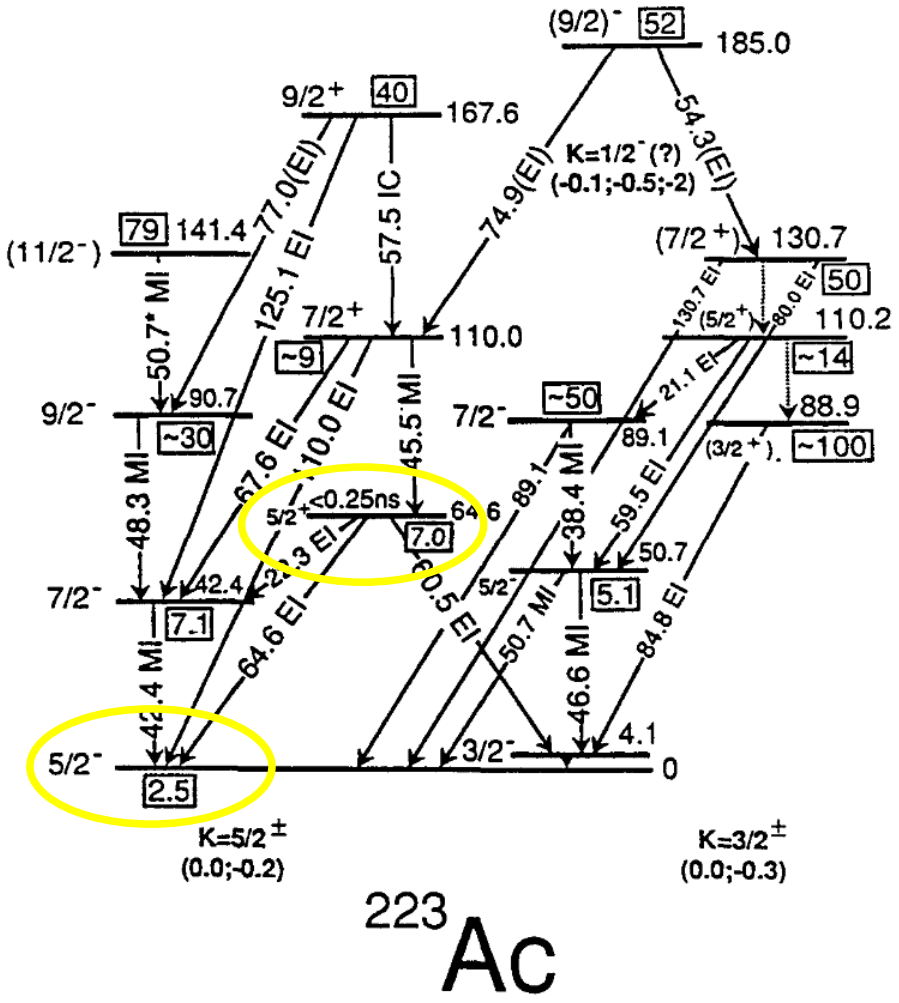


Static octupole deformation

Interpretation



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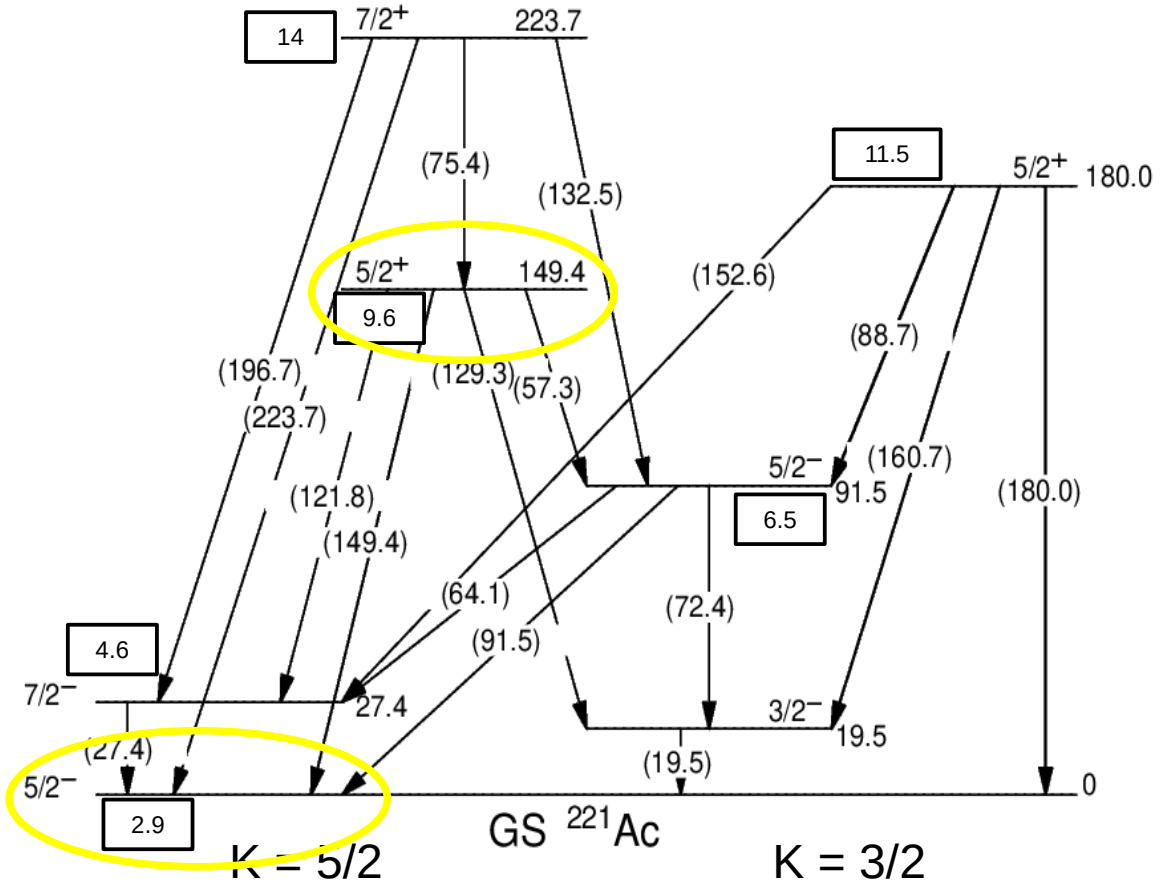
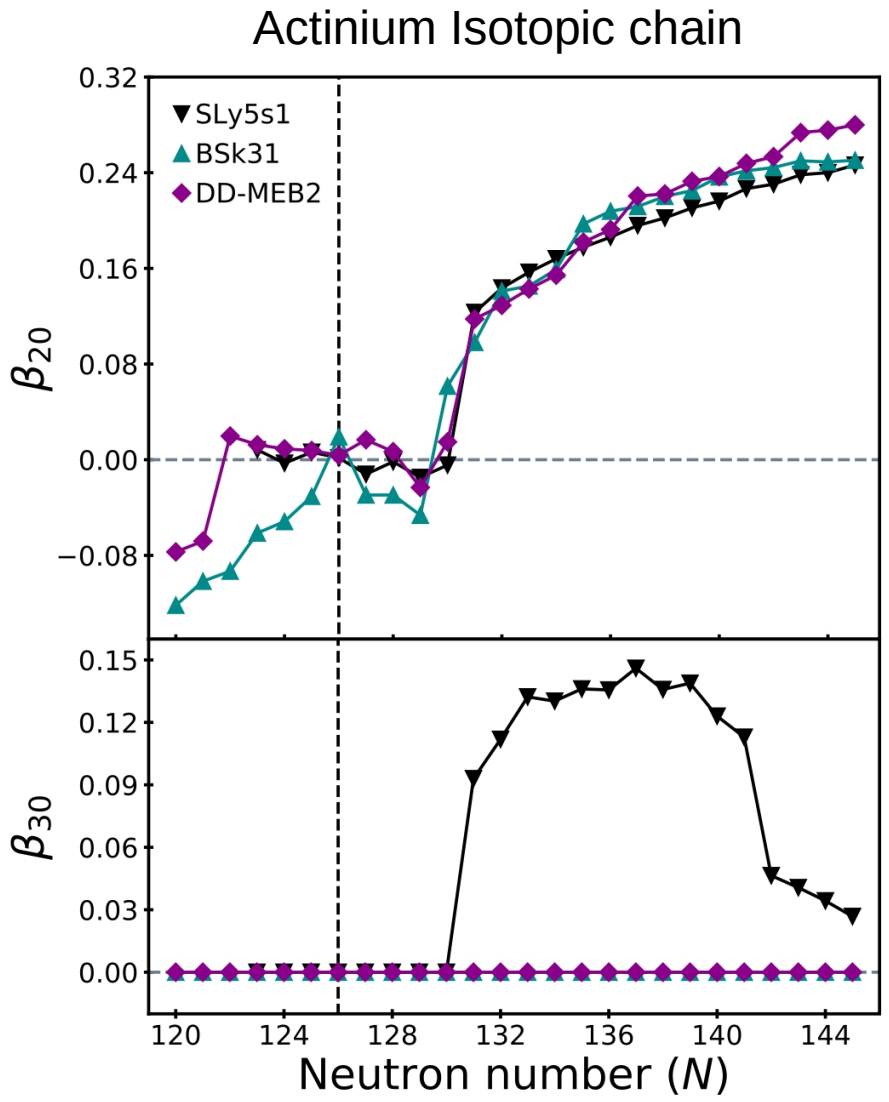


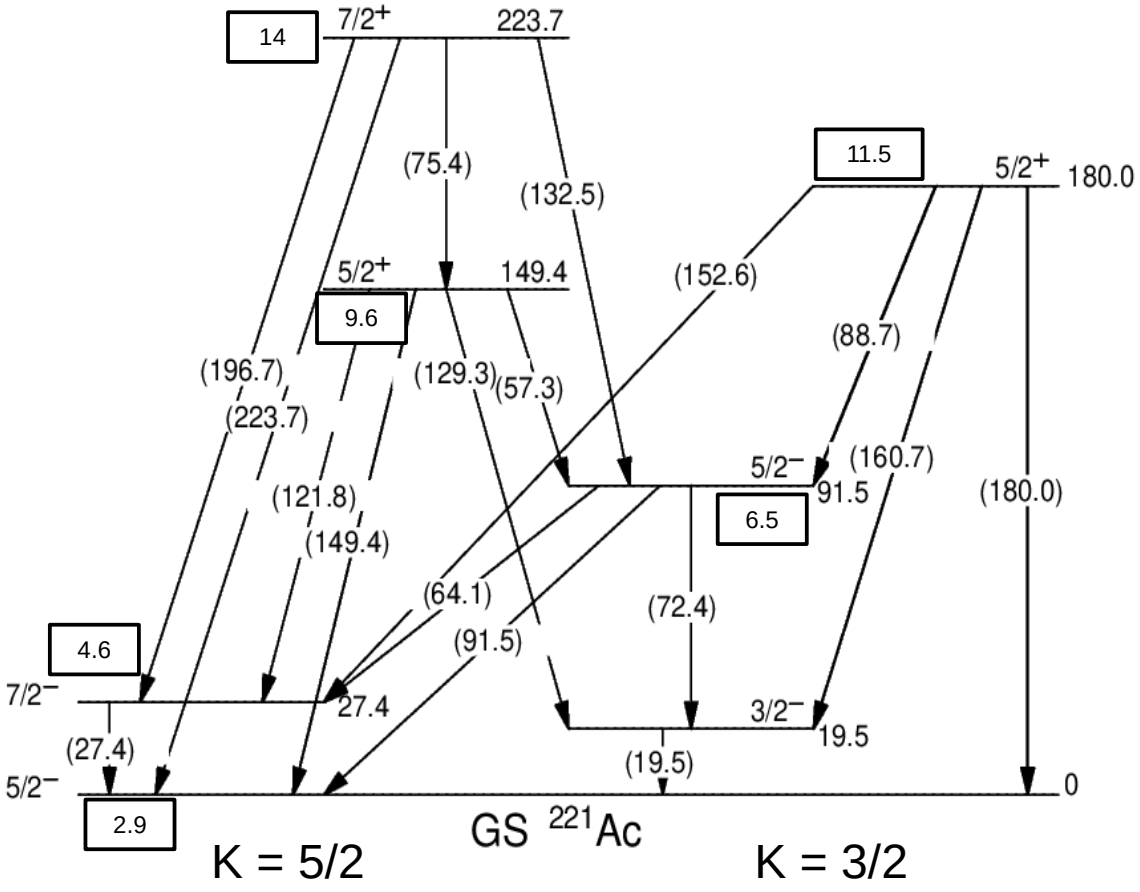
Static octupole deformation

Transition towards the octupole vibration region

Interpretation



Verstraelen et al. PRC 100, 044321 (2019).



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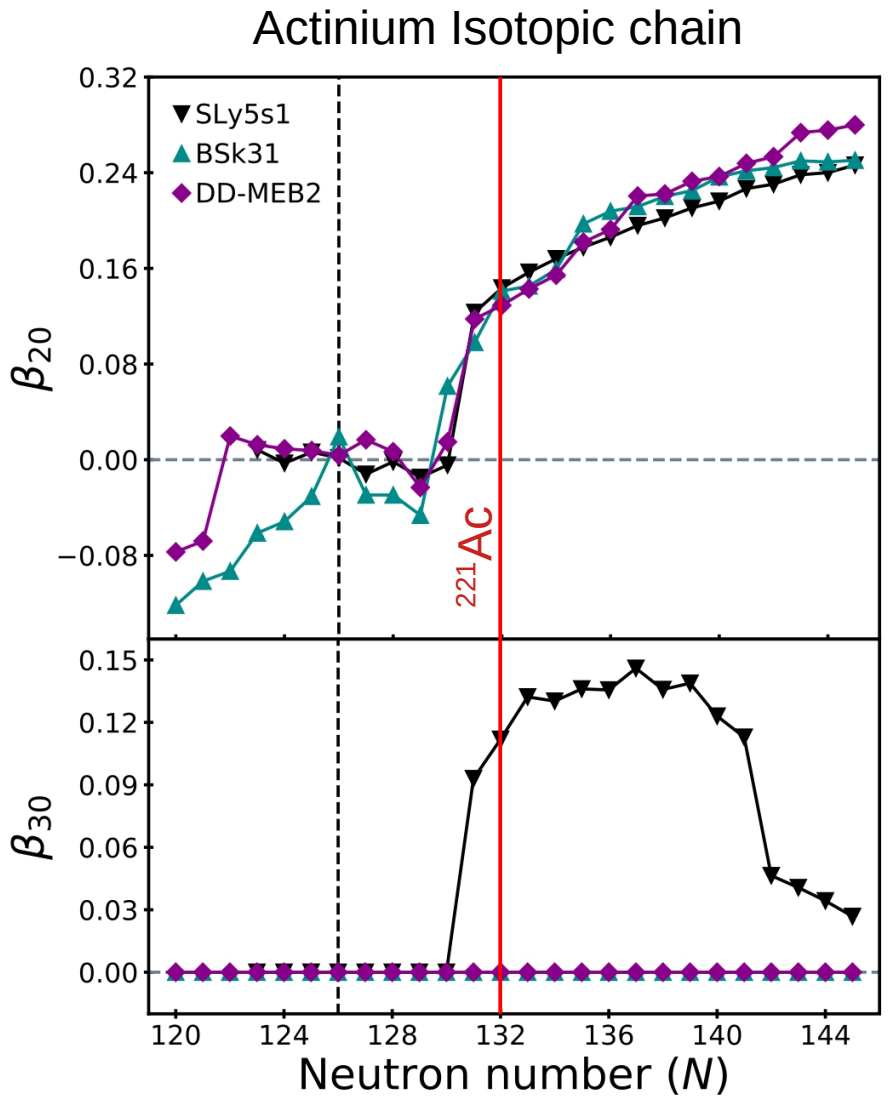

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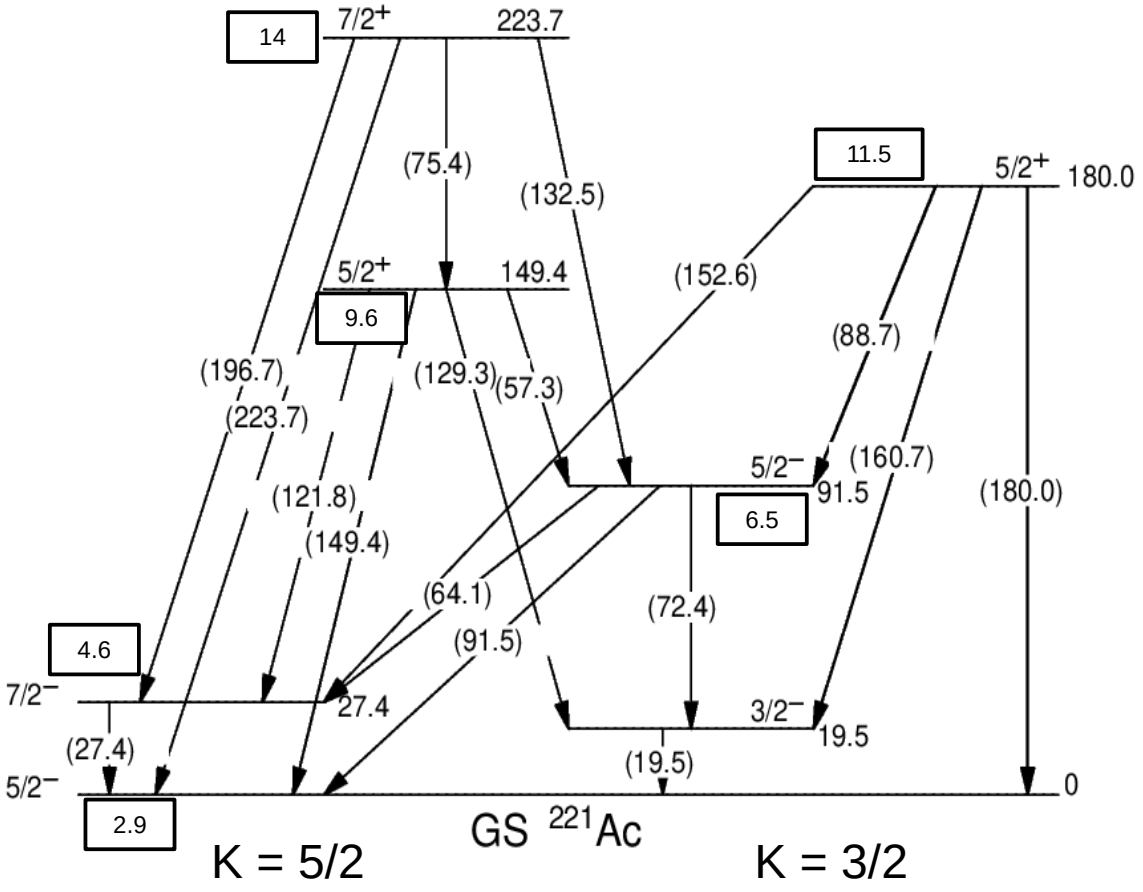

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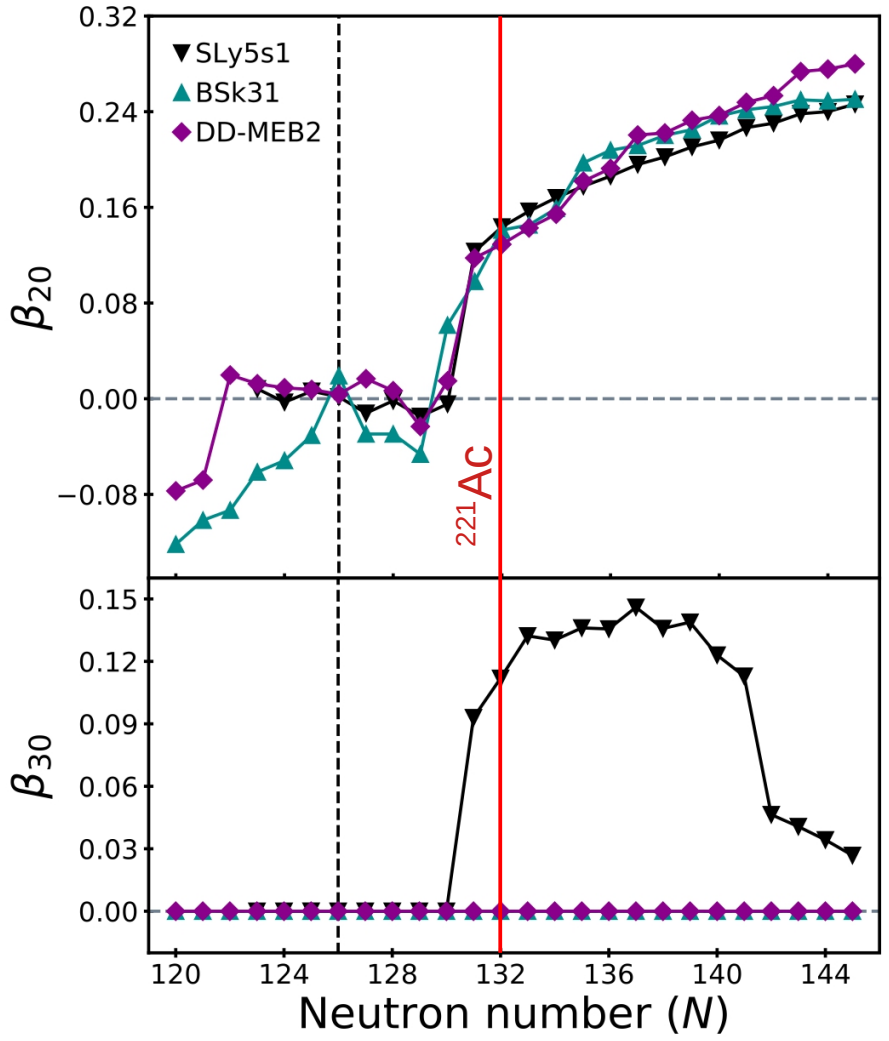
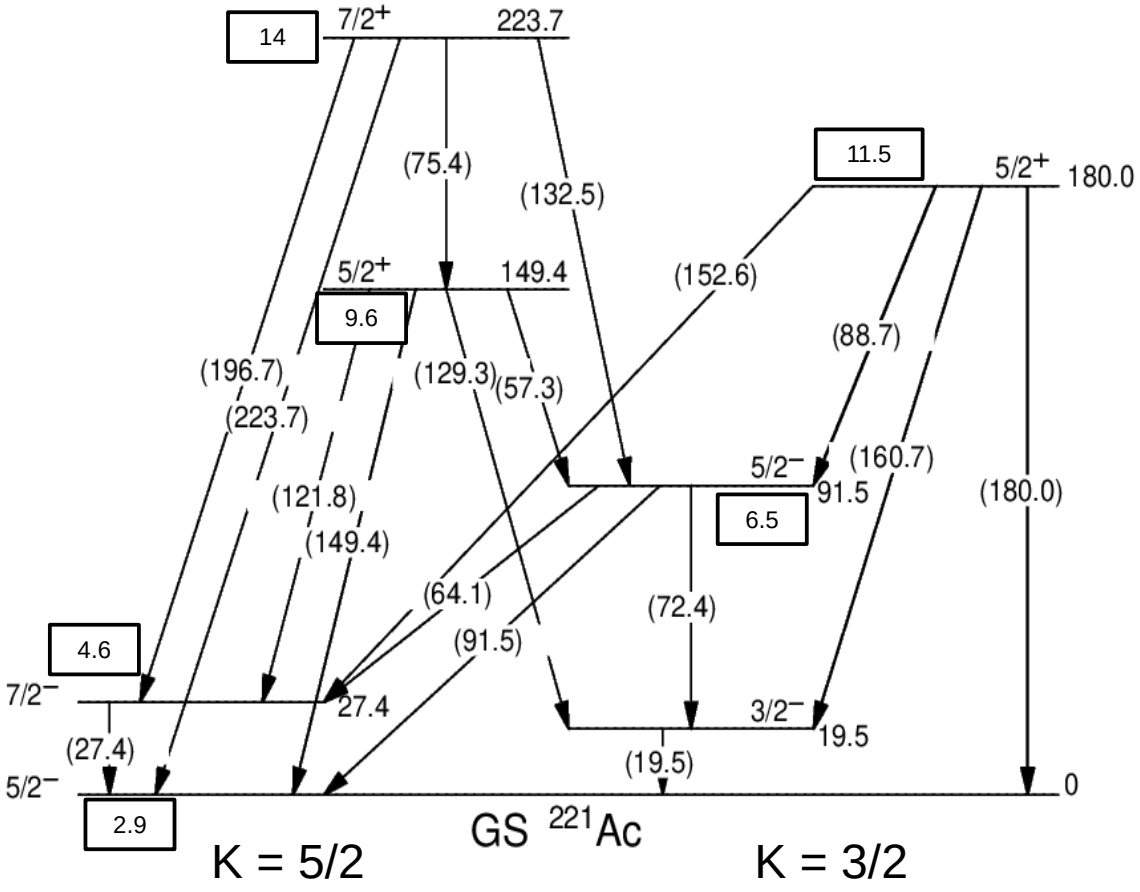
Actinium Isotopic chain



Verstraelen et al. PRC 100, 044321 (2019).

Rey-herme *et al.*,
PRC 108, 014304 (2023)



Static octupole deformation

Transition towards the octupole vibration region

Summary

- Production of neutron deficient actinides at IGISOL using the **^{232}Th(p,xn)$^{233-x}$Pa reaction**.

- Alpha, γ and electron decay spectroscopy of ^{225}Pa

- Signature of a **static octupole deformation in ^{221}Ac**

- Indication of a **transition towards octupole vibration** for more neutron deficient actinium isotopes

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- Production of neutron deficient actinides at IGISOL using the **^{232}Th(p,xn)$^{233-x}$Pa reaction**.

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- Indication of a **transition towards octupole vibration** for more neutron deficient actinium isotopes

However:

- Insufficient detection efficiencies (especially for conversion electrons)

- Signs of a potential missing state

SEASON
(Spectroscopy Electron Alpha in Silicon bOx couNter)

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Two main goals:
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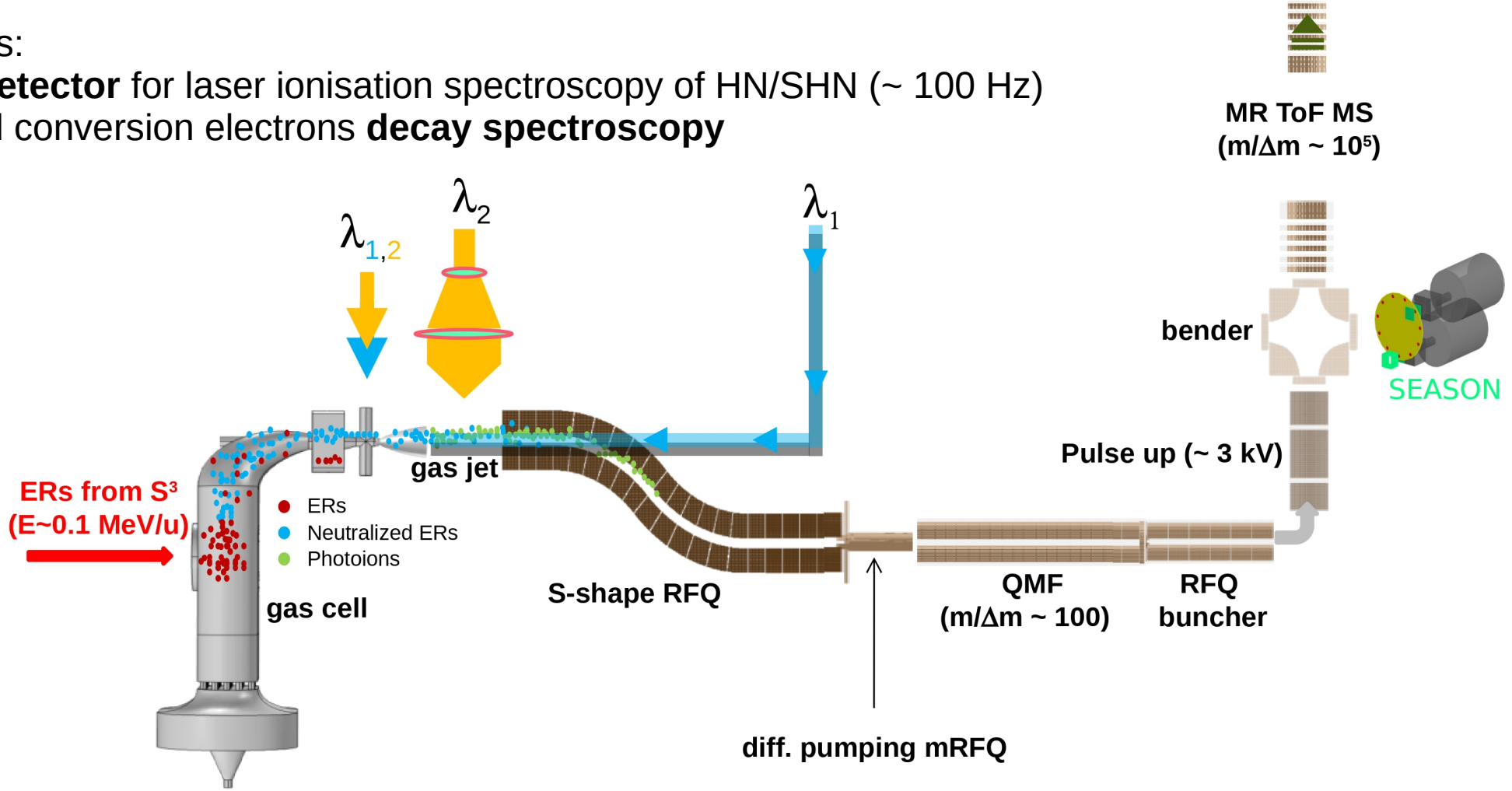

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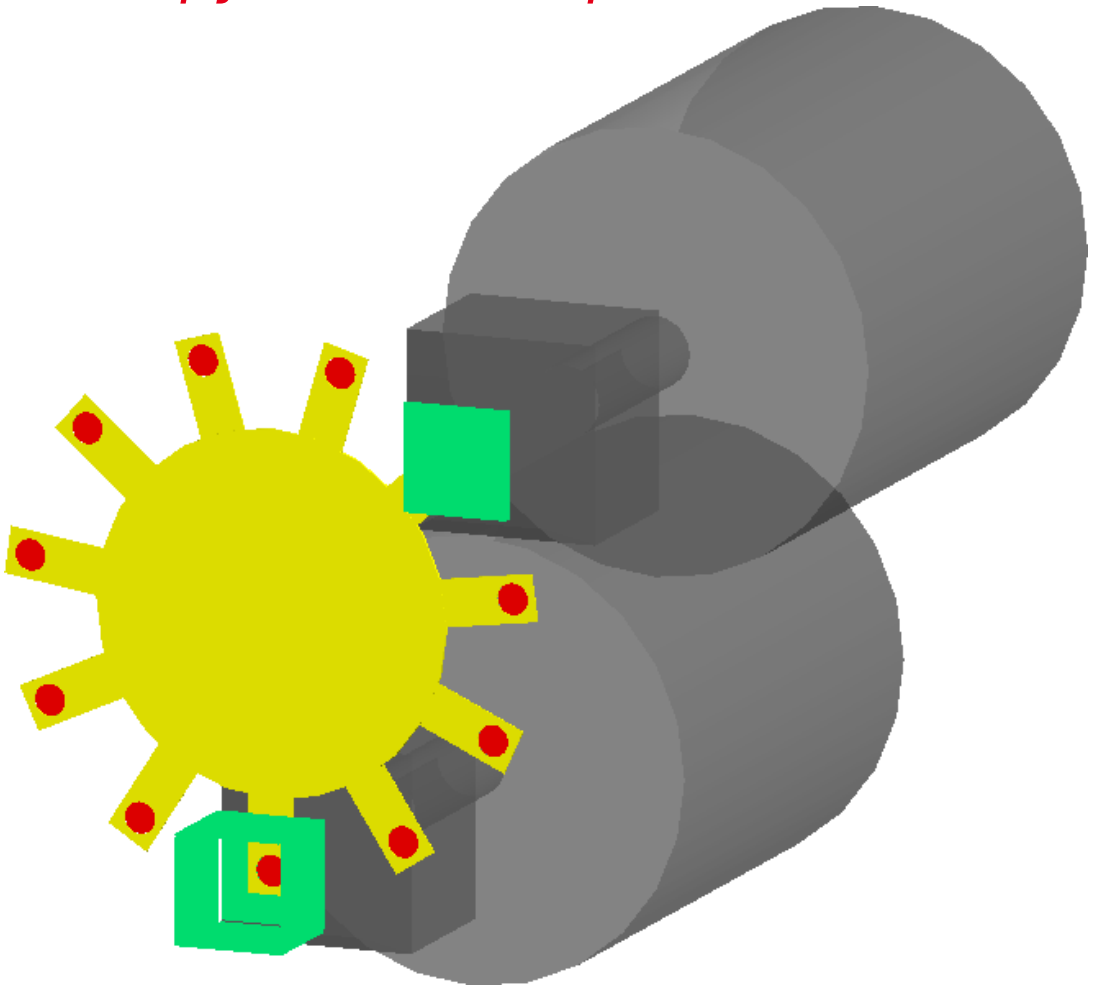

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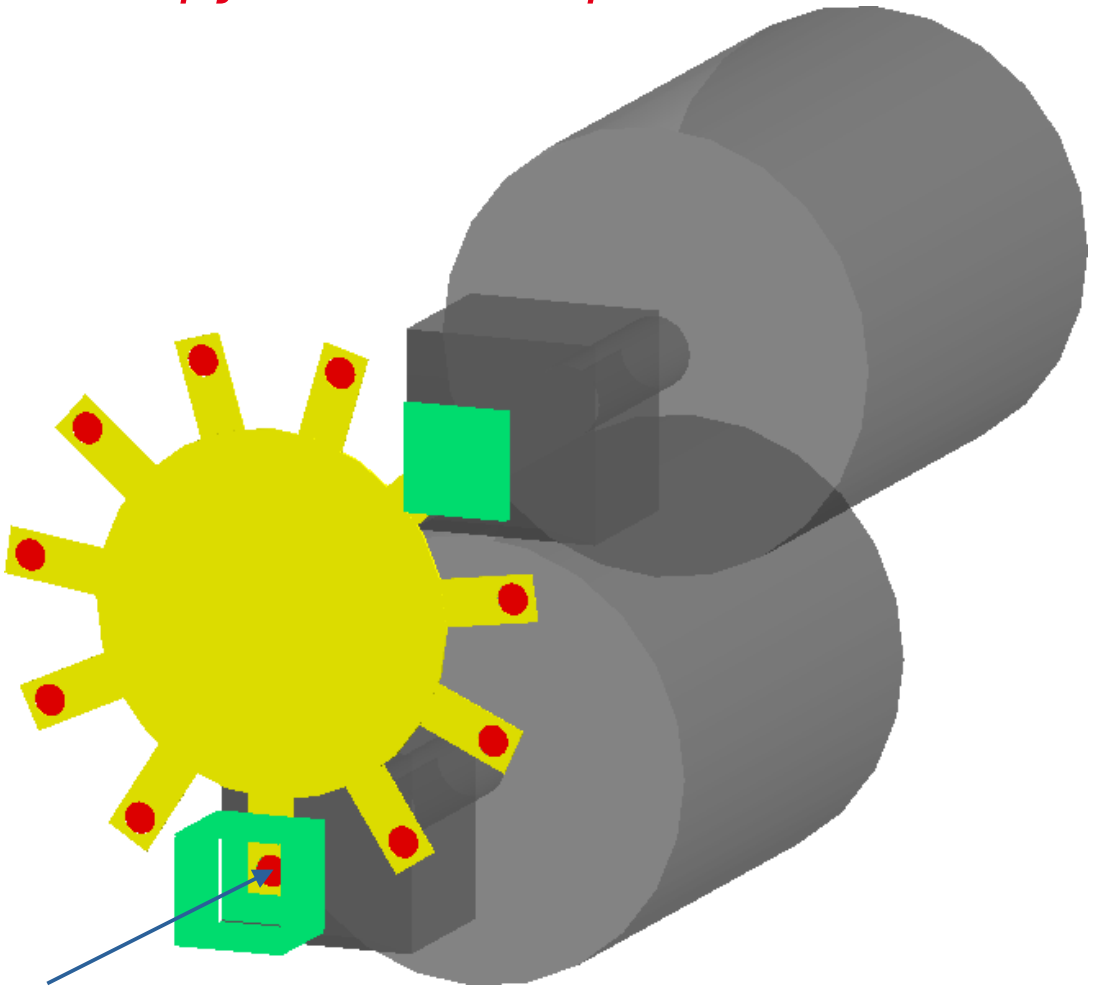

Laser ionized atoms
3 - 30 keV (~100 Hz)

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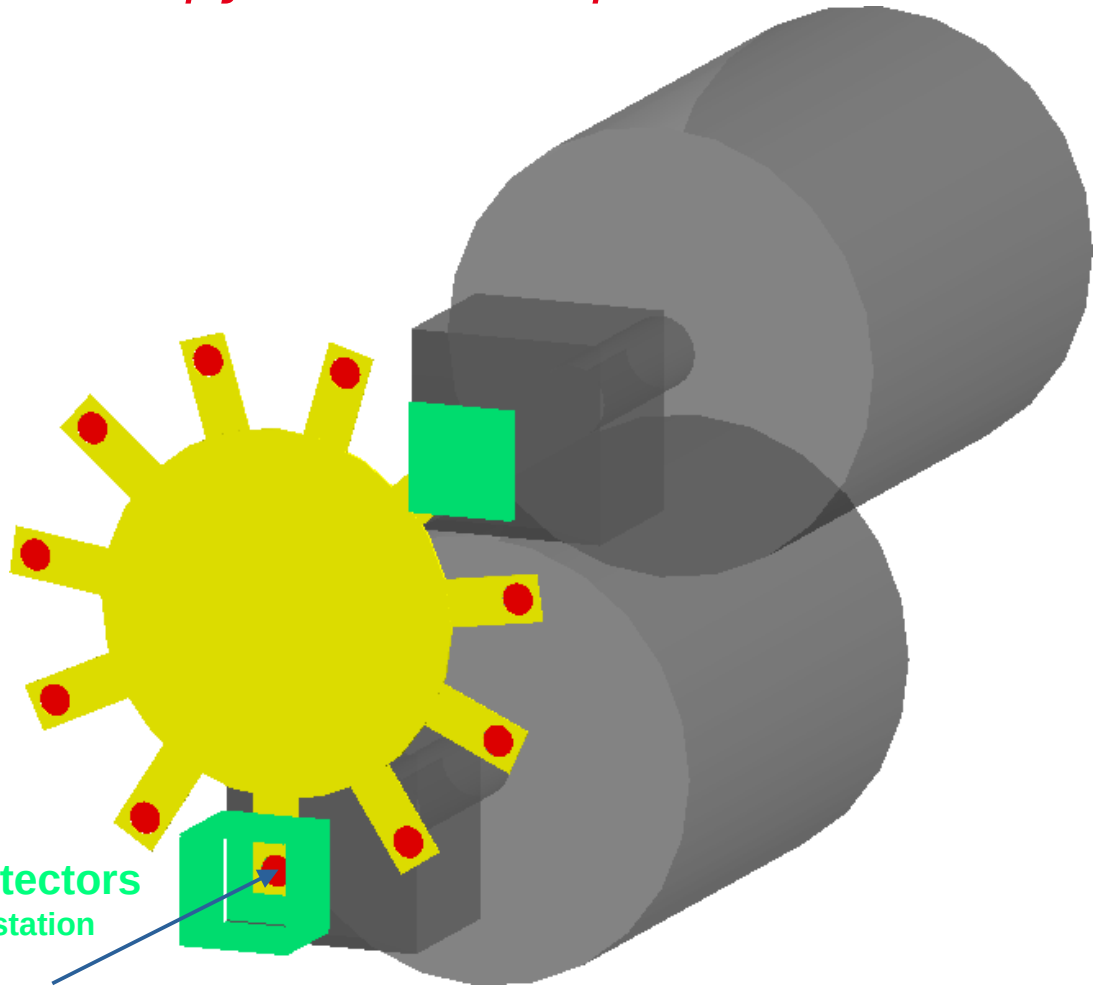

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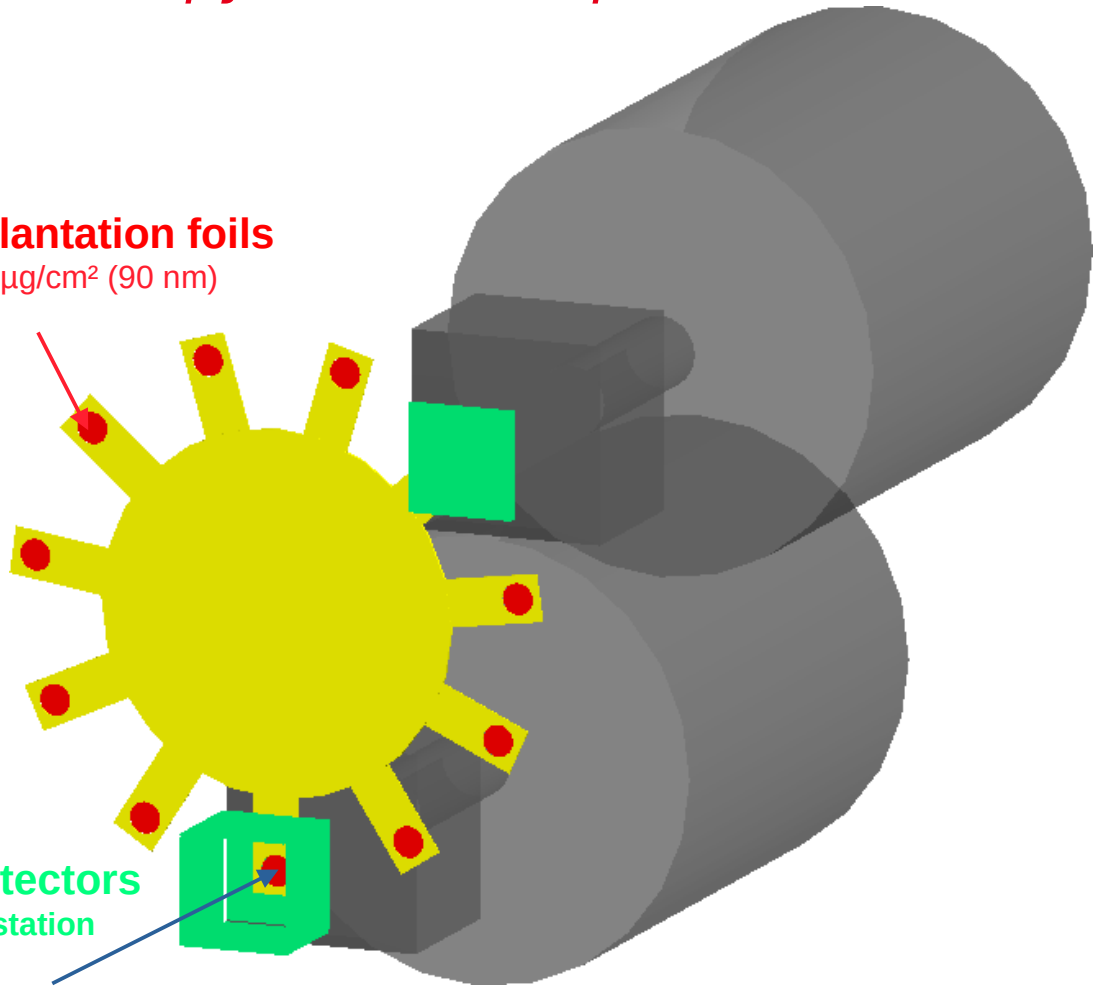

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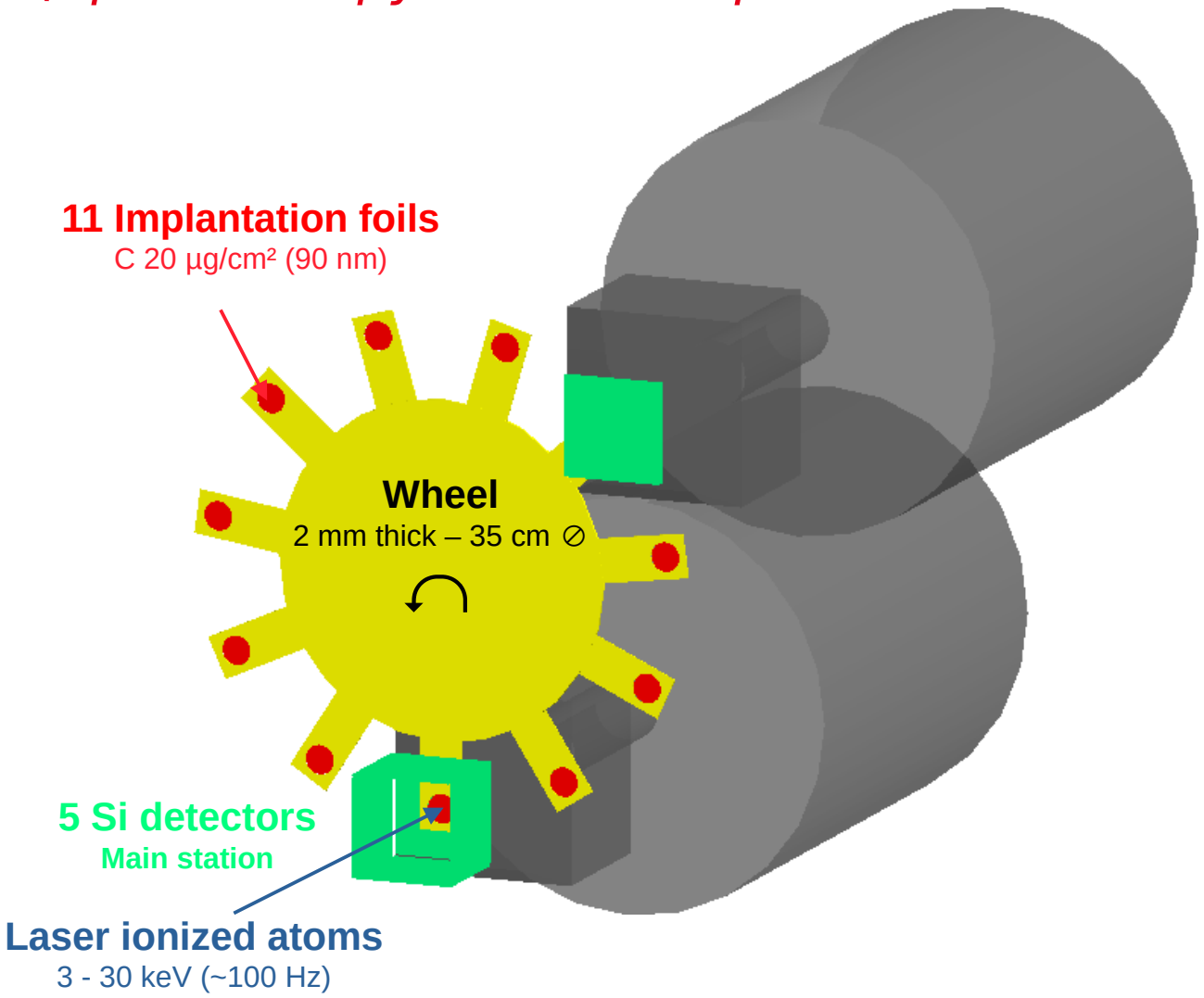

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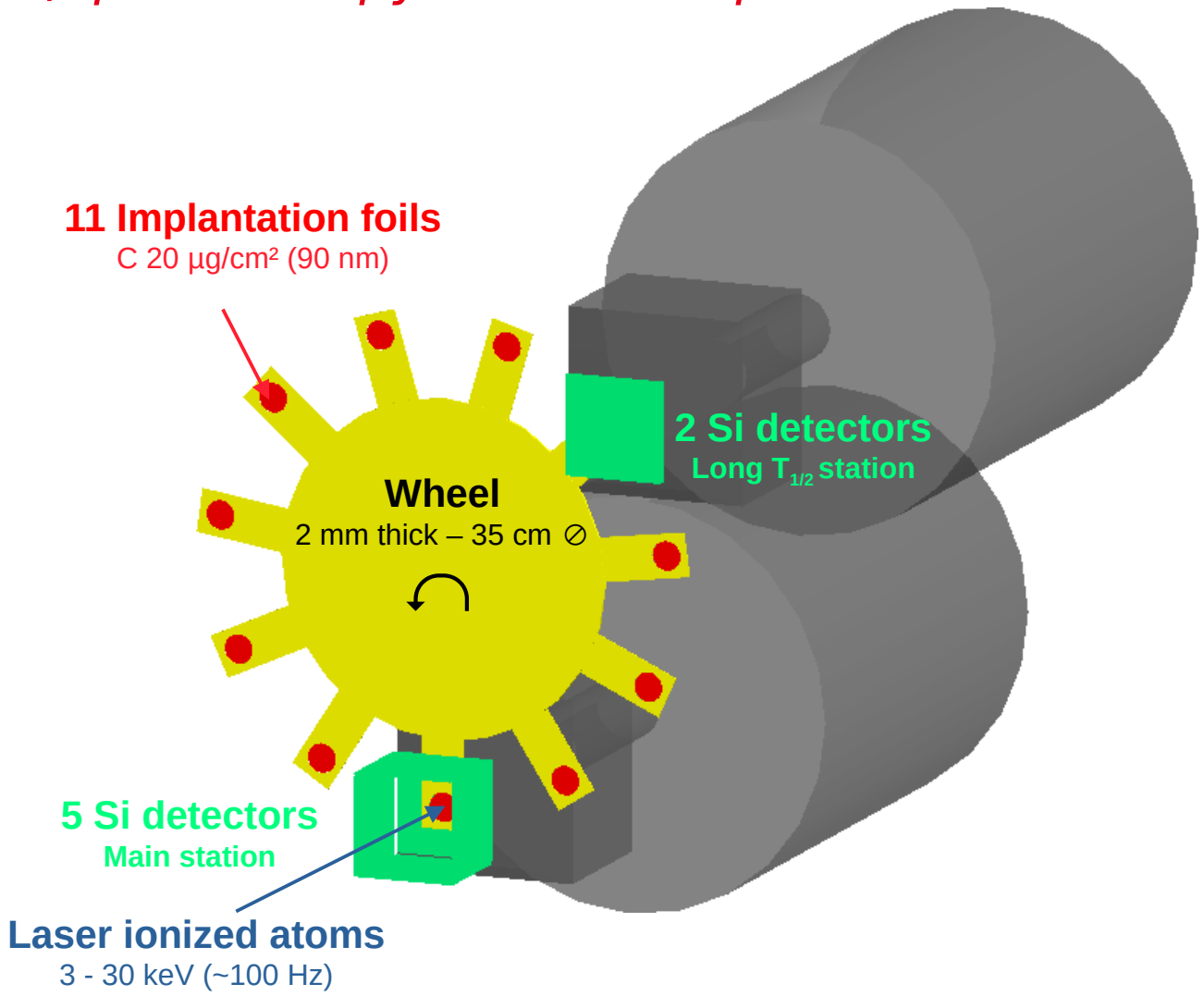

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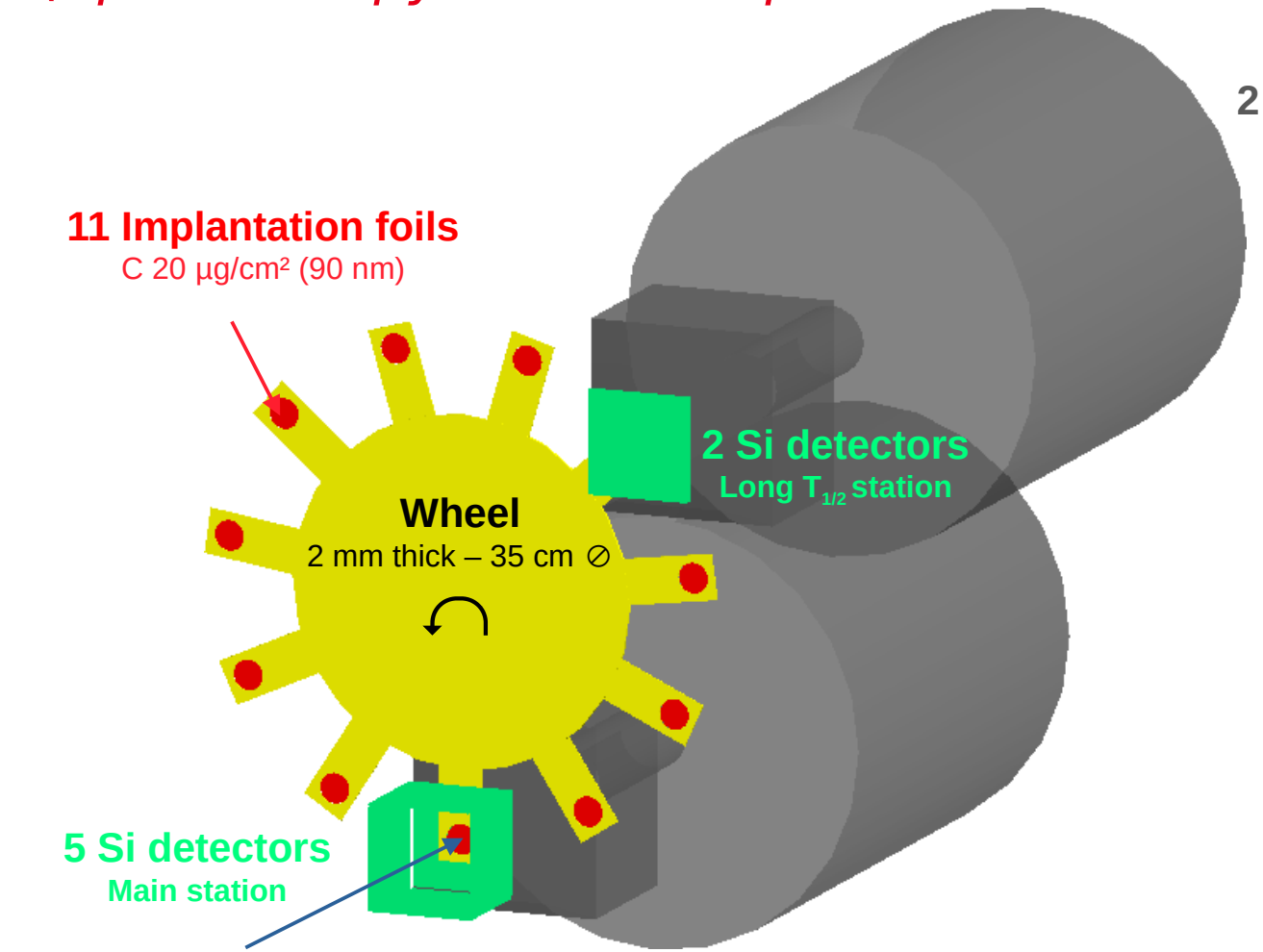

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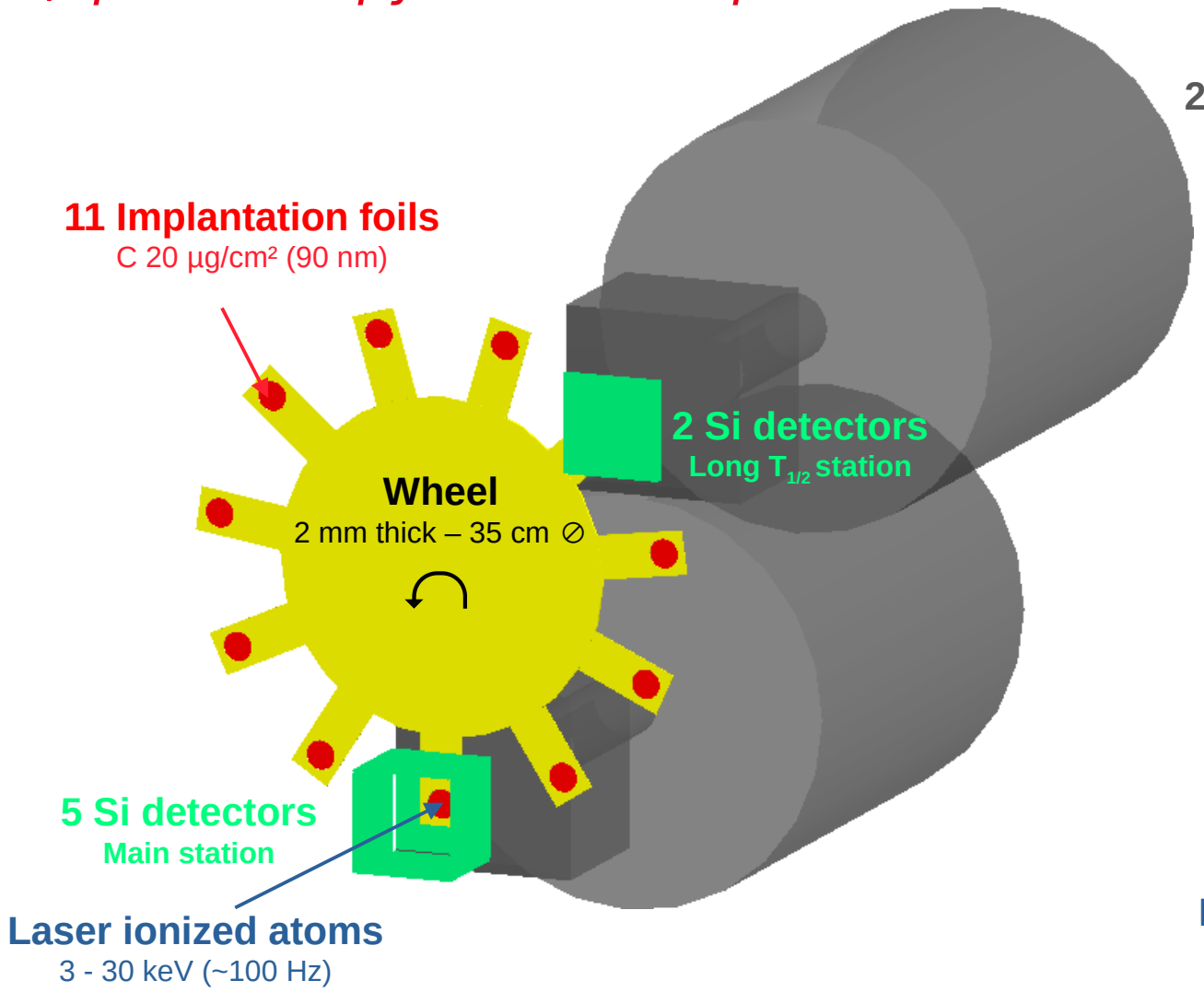

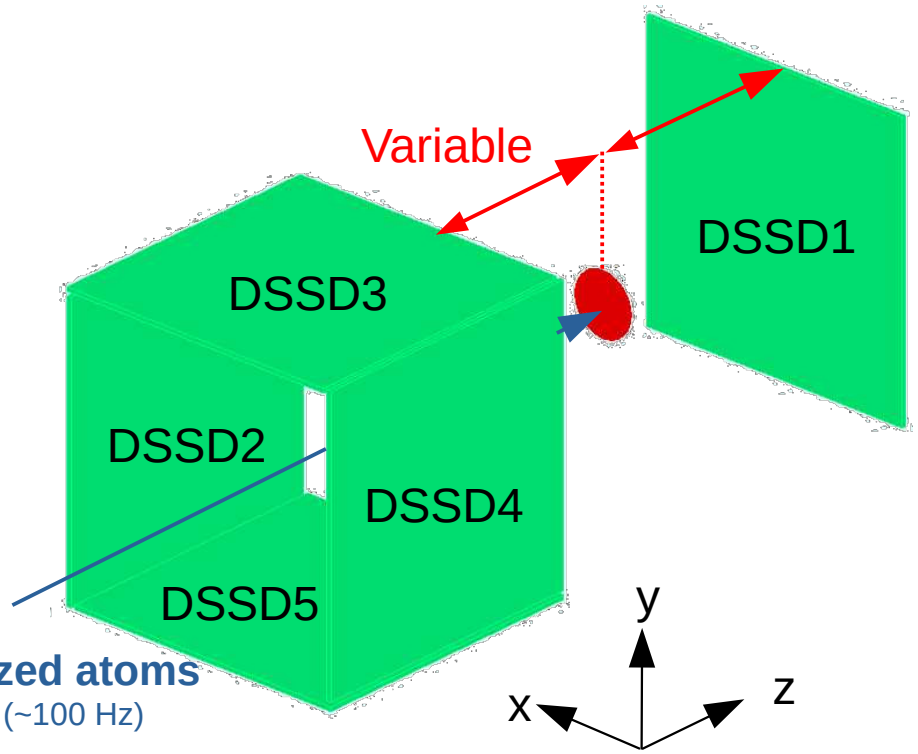

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Energy resolution (FWHM)	15 keV (α-particles) 7 keV (electrons)
Energy threshold	20 keV
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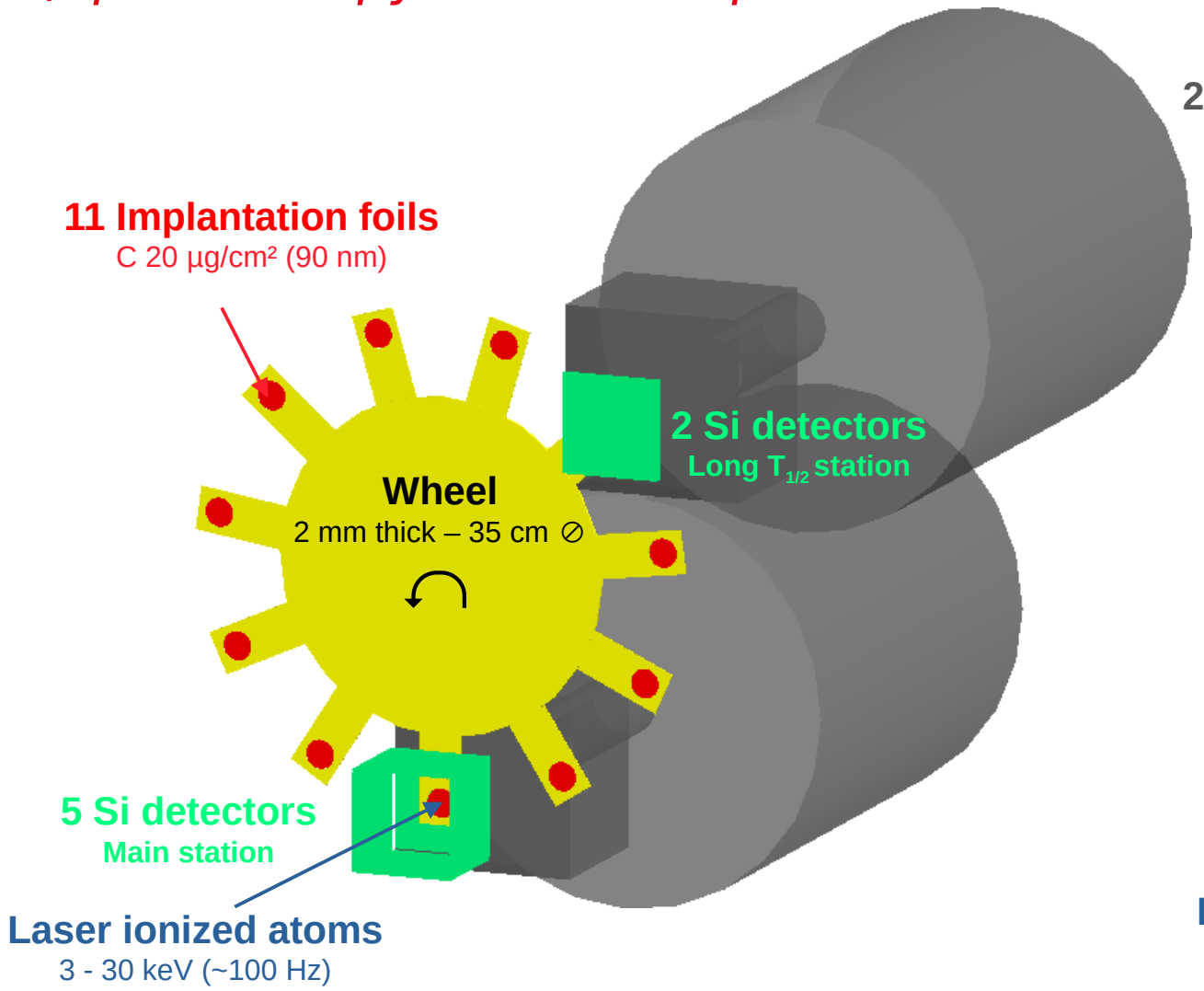

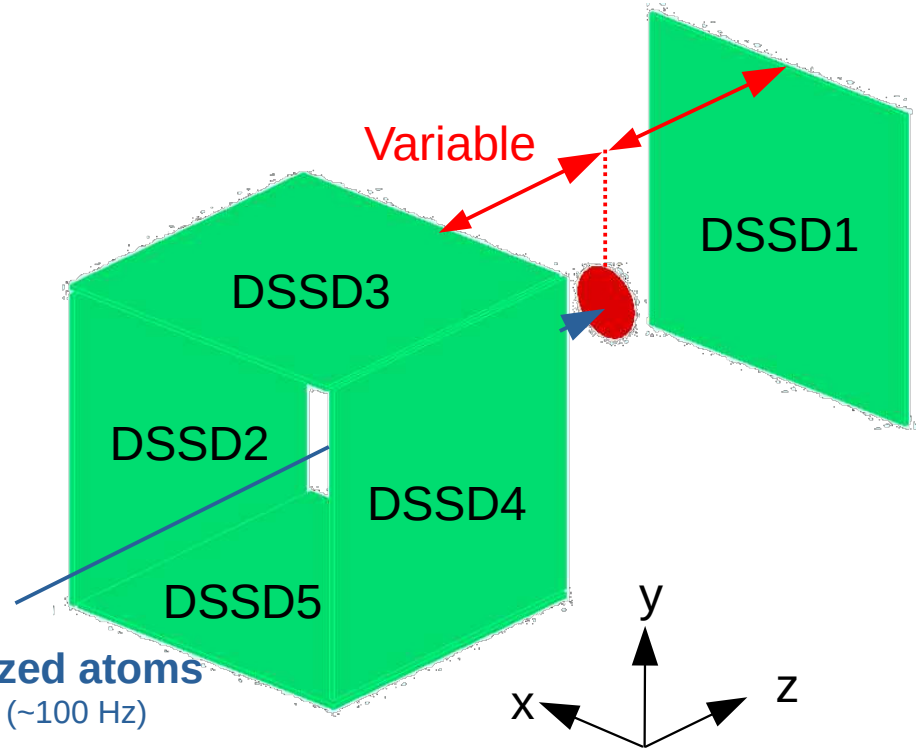

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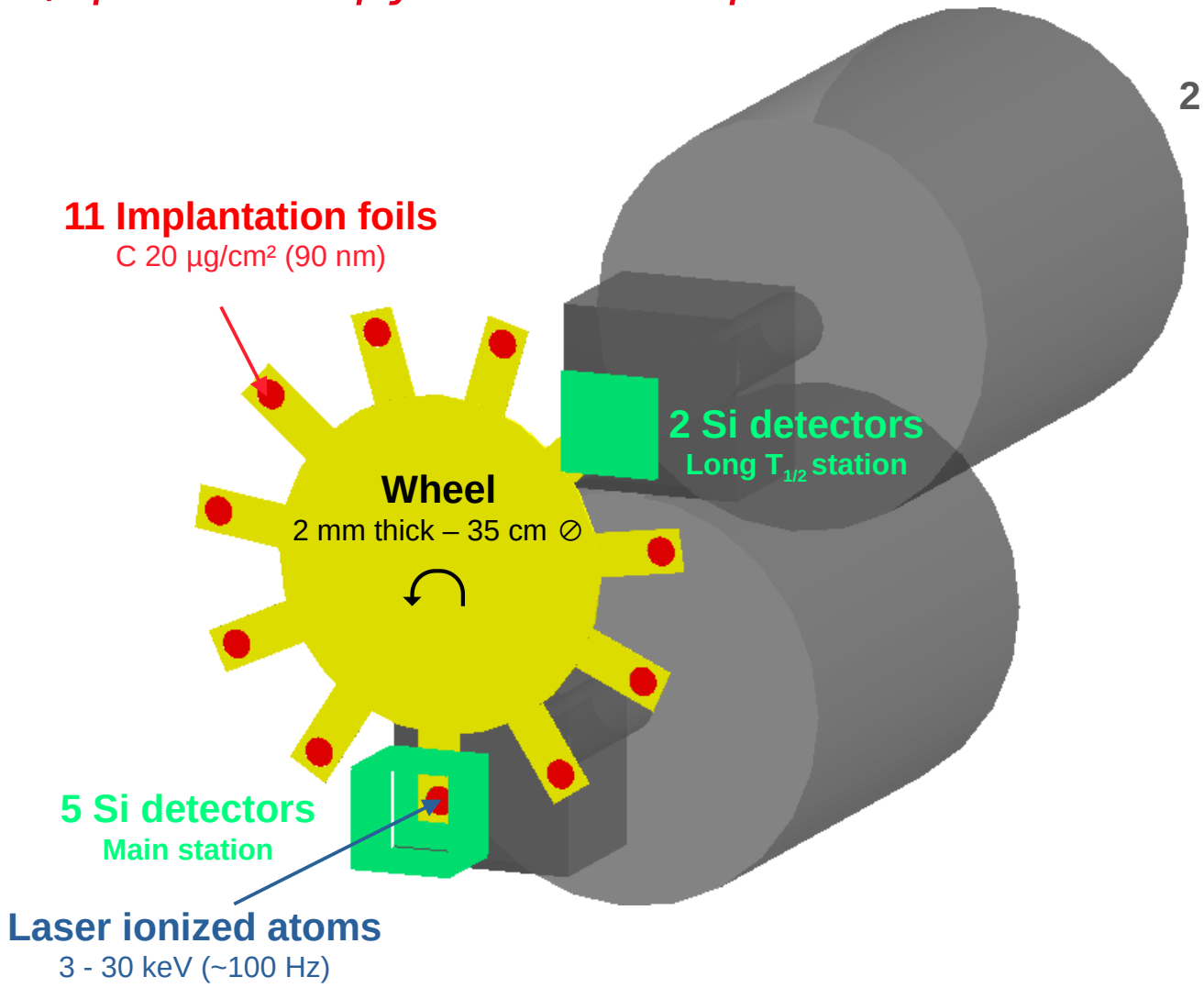

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	I262	SEASON
α-particles detection efficiency	~ 30 %	~80 %
α-particles energy resolution (FWHM)	25 – 50 keV	15 keV
Electron detection efficiency	~ 1 %	~ 50 %
electron energy resolution (FWHM)	~ 3 keV	7 keV

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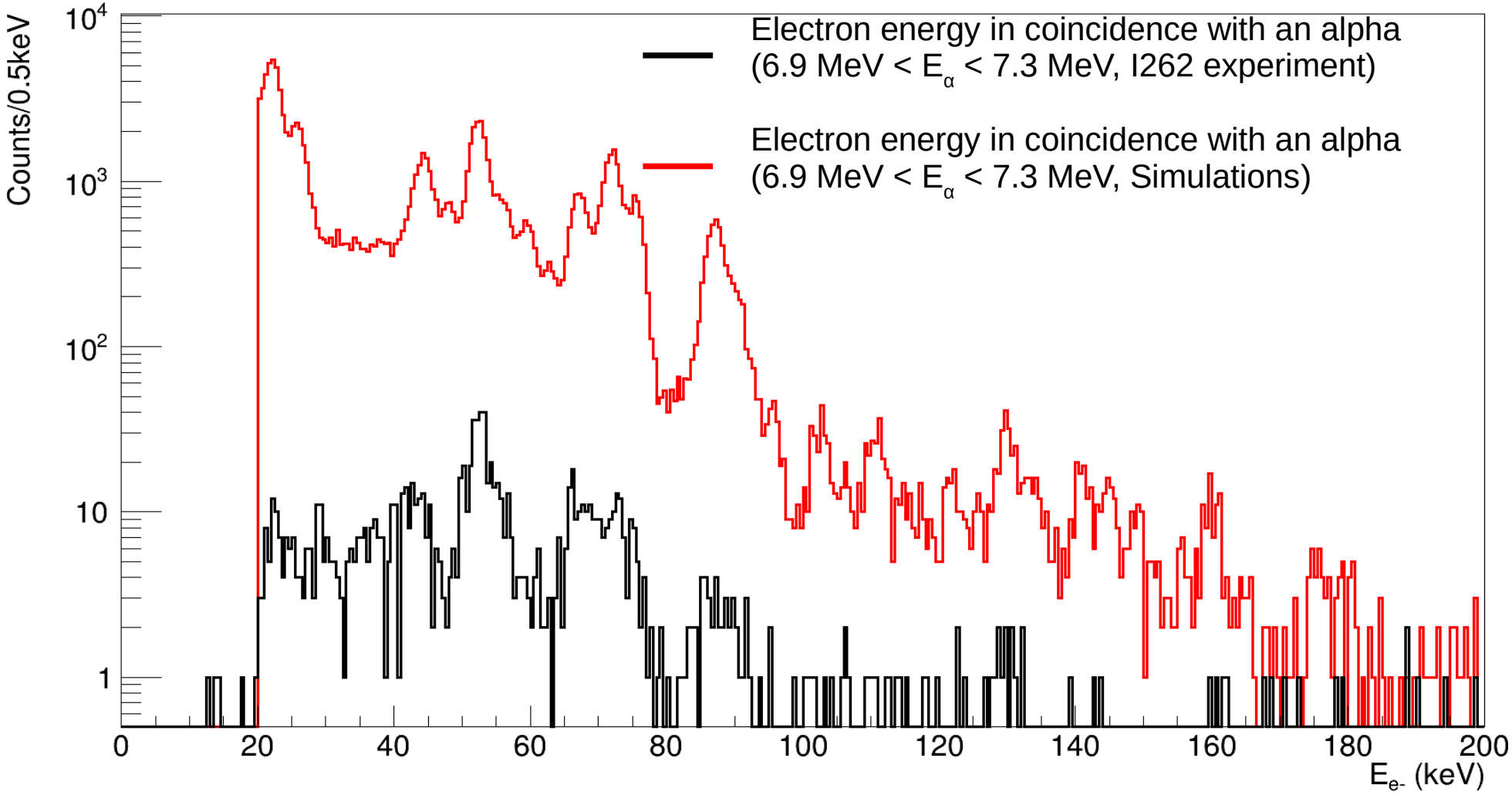

Perspectives

SEASON@IGISOL:

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Thank you for your attention !