DE LA RECHERCHE À L'INDUSTRIE

Decay spectroscopy of ^{225}Pa: Toward laser spectroscopy of neutron-deficient actinides

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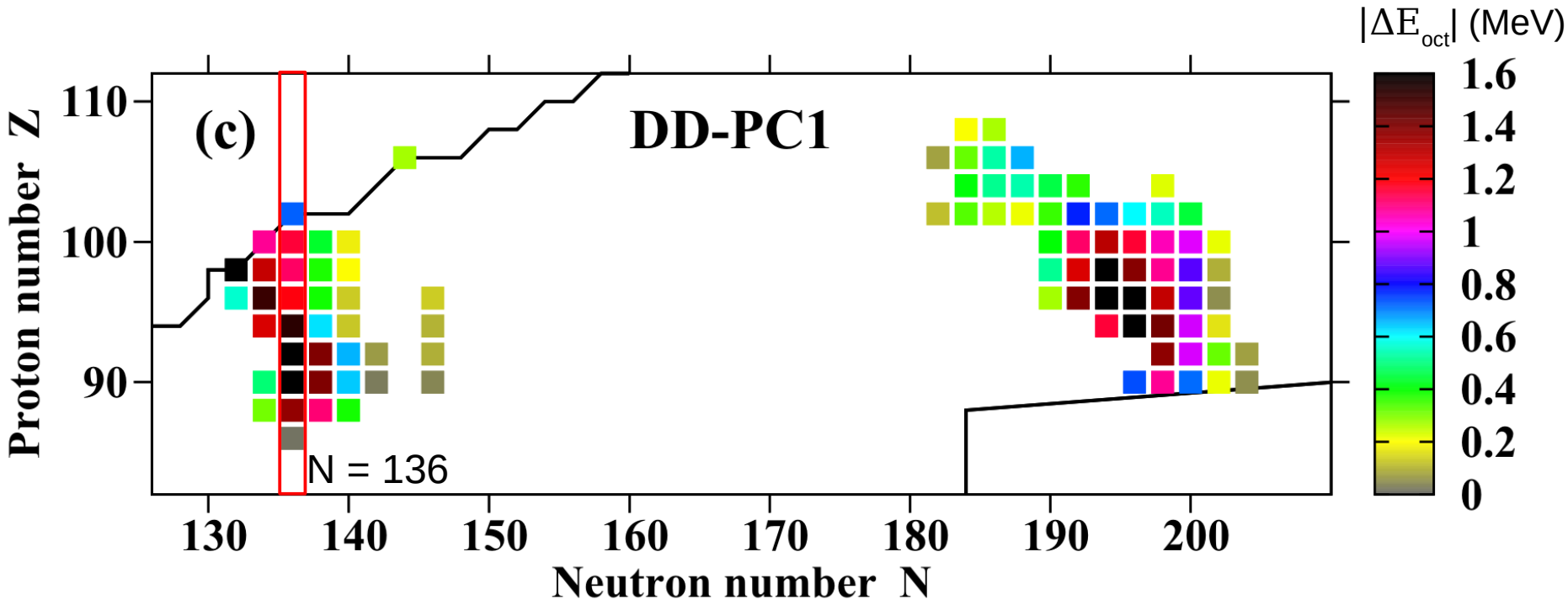
Supervised by M. Vandebrouck (CEA/Irfu/DPhN)
In collaboration with I. Moore, I. Pohjalainen and A. Raggio (University of Jyväskylä)

Vth ISOL-France Workshop
22 March 2023

Physics motivation

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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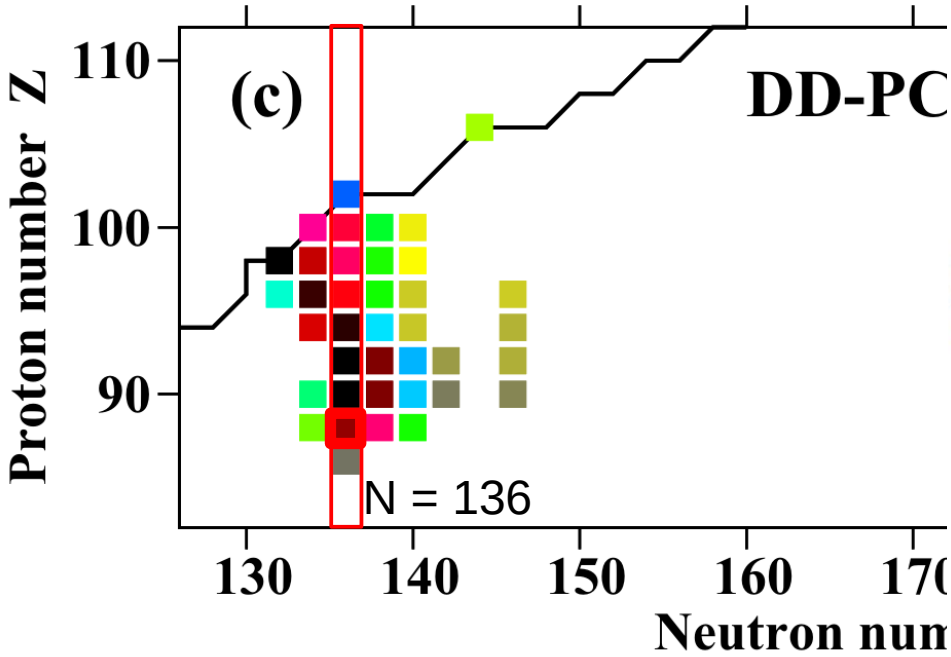
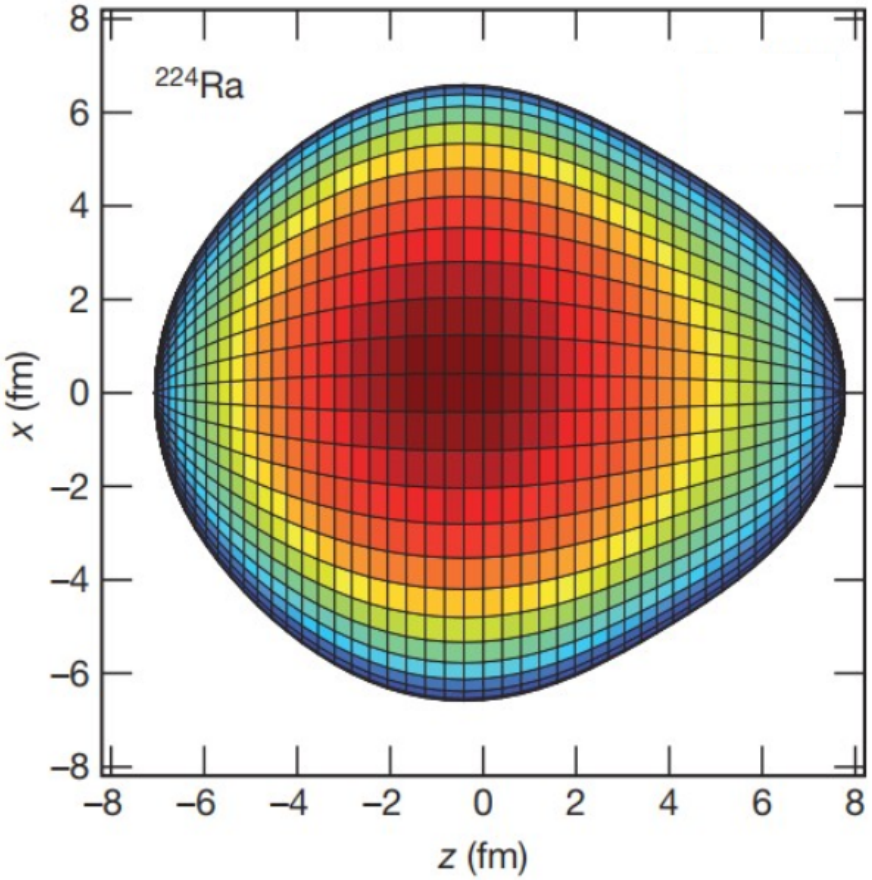


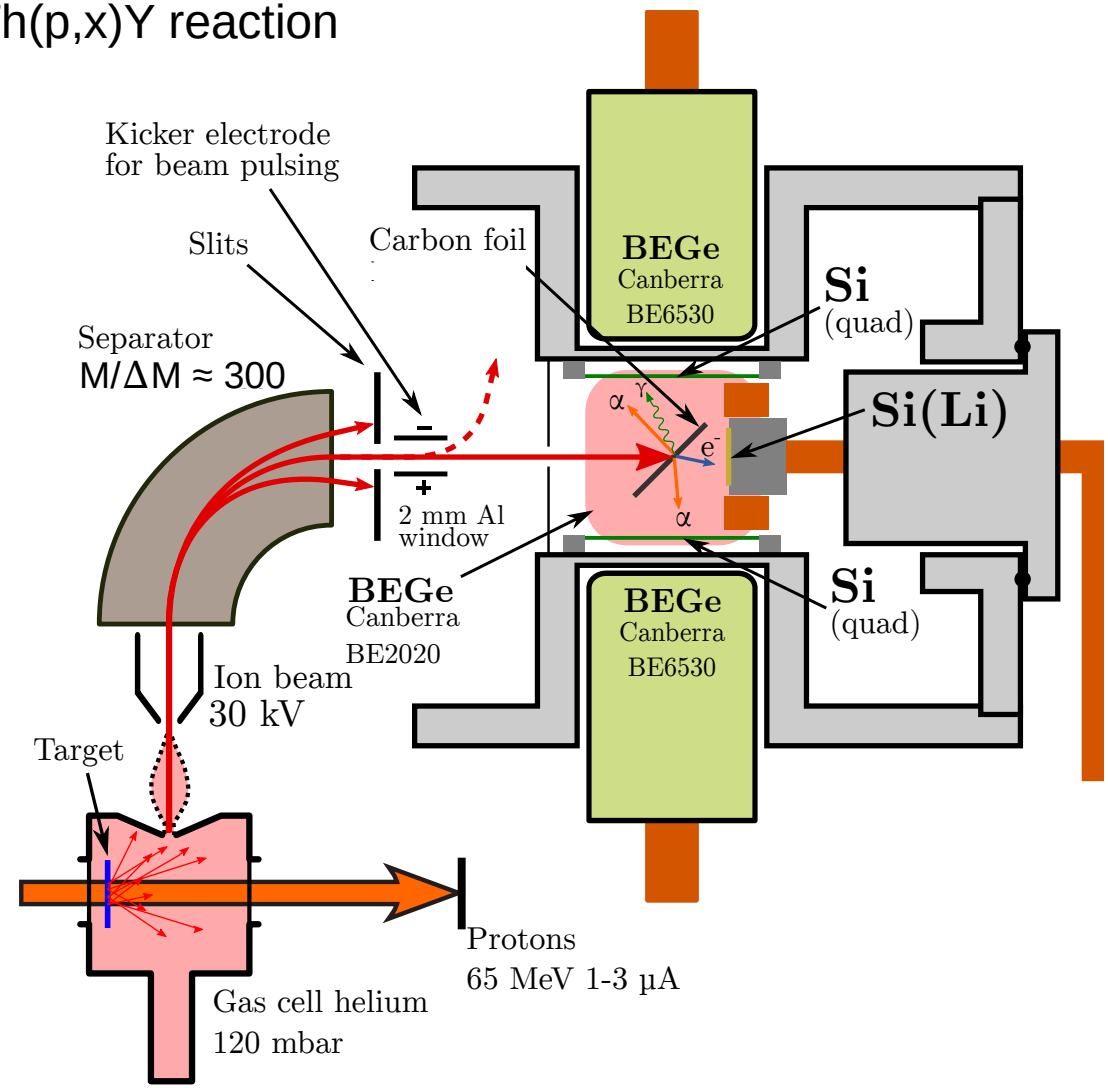
S. E. Agbemava et al.

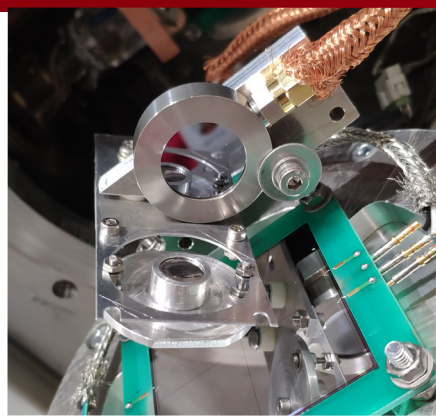


L. P. Gaffney et al. Nature 497 (2013)

I262 experiment at IGISOL

^{232}Th(p,x)Y reaction





Analysis :

^{225}Pa → ^{221}Ac → ^{217}Fr

Existing literature:

^{225}Pa decay data

Element	Our work	
	E_α(keV)	I(%)
^{225}Pa	7170(5)	17(1)
	7235(5)	30(2)
	7261(5)	53(2)
^{221}Ac		
	7373(5)	6(1)
	7437(5)	20(2)
	7641(5)	74(3)
^{217}Fr	8312(5)	
^{213}At	9080(5)	

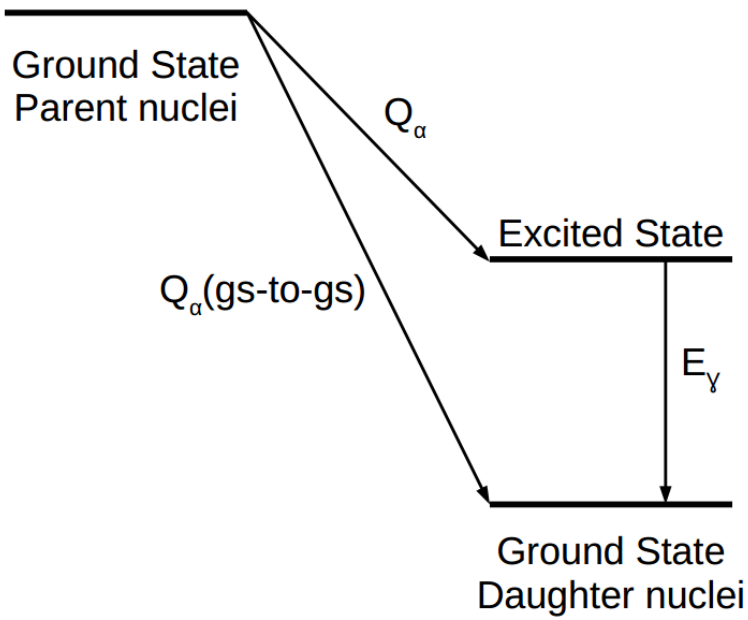
(1988) Nuclear Inst. and Methods in Physics Research, B, 31 (3), pp. 483-486

^{225}Pa decay spectroscopy

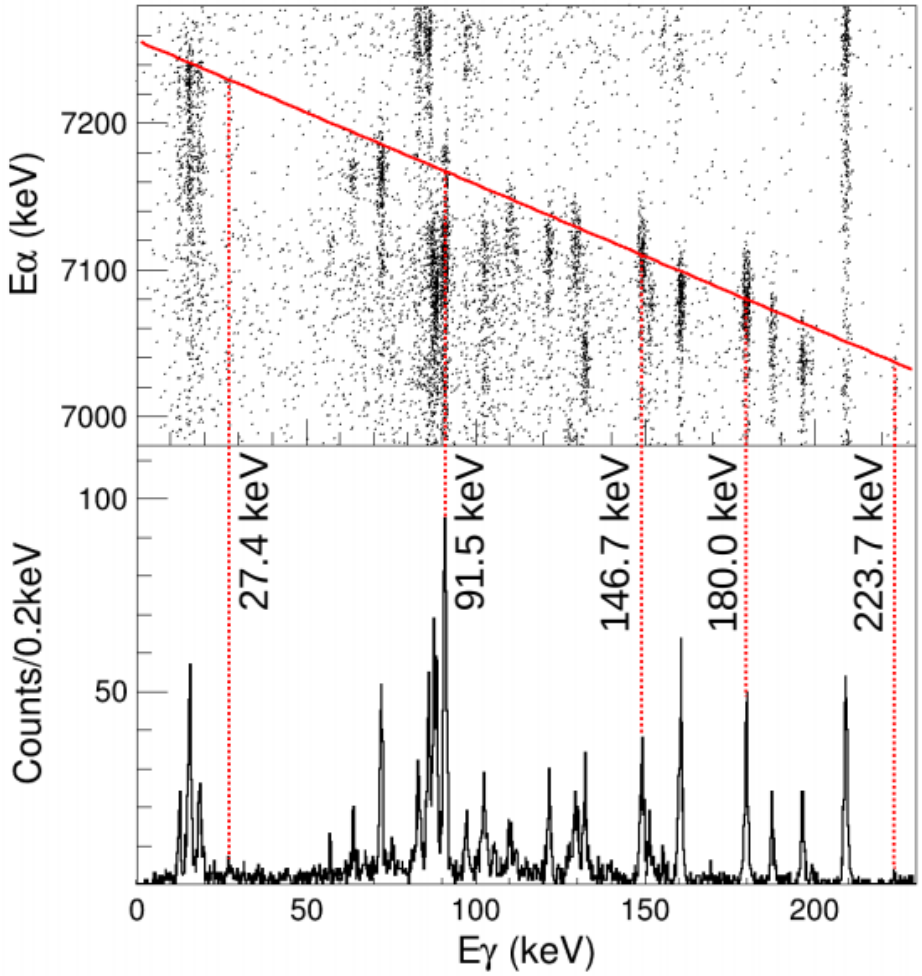
Main tool for the analysis:

$$Q_\alpha(gs - to - gs) = Q_\alpha + E_\gamma$$

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



Alpha-gamma coincidences for mass 225

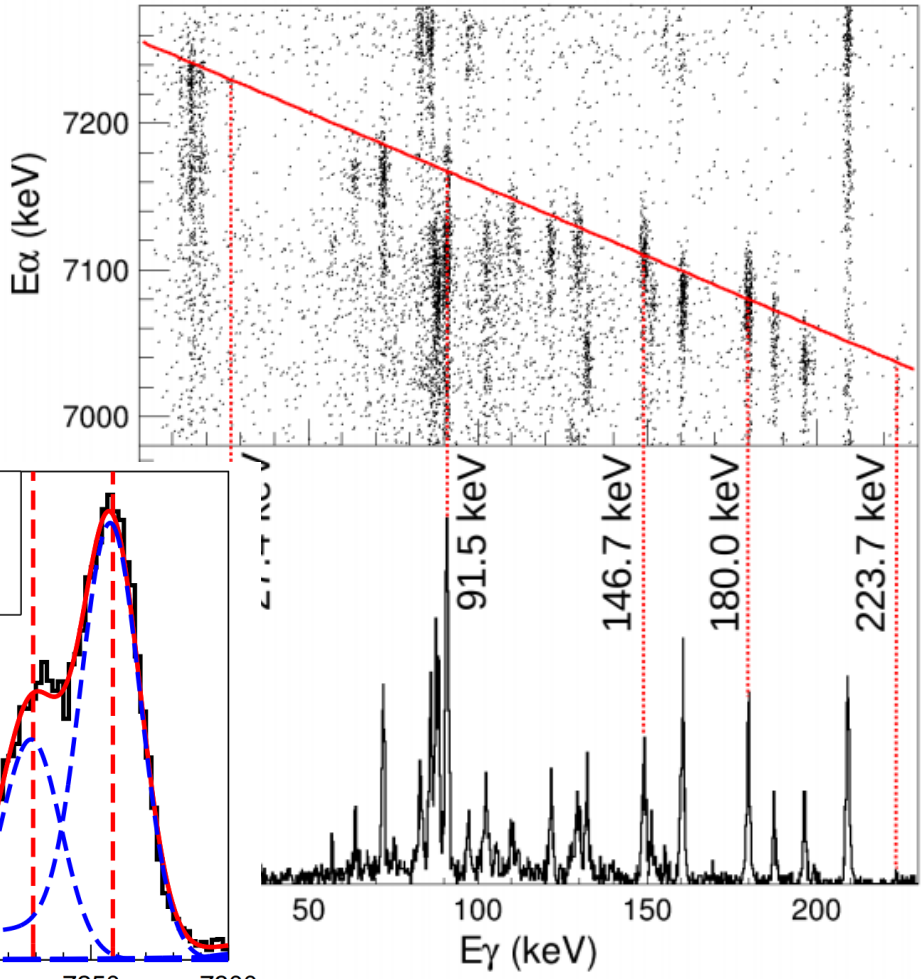


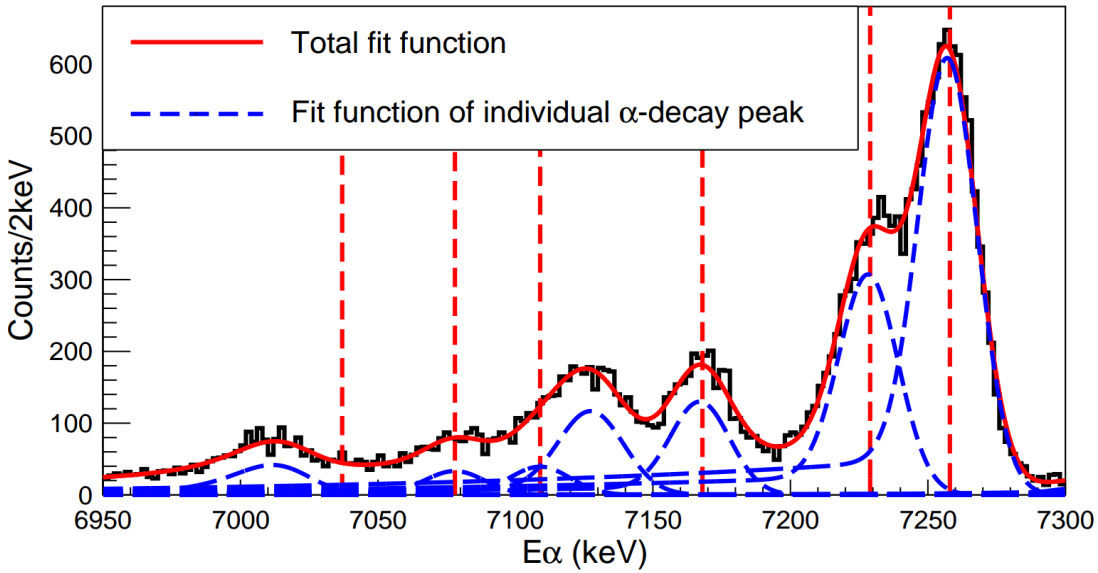
^{225}Pa decay spectroscopy

Analysis process:

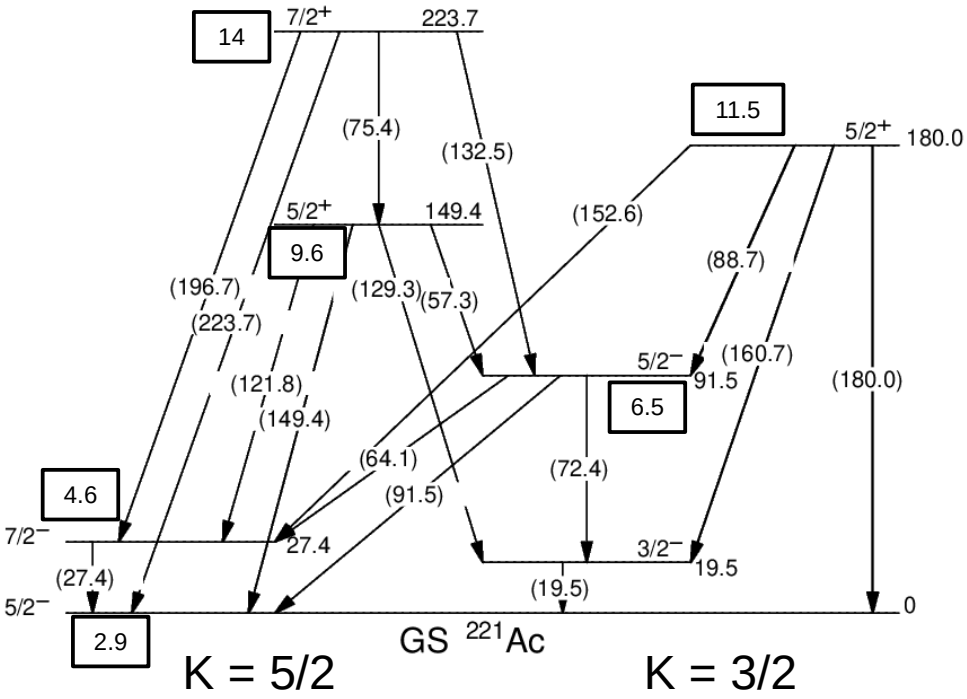
- Energy and efficiency calibration
- Level identification through coincidences
- Energies and intensities extraction
- Level scheme reconstruction

Alpha-gamma coincidences for mass 225





^{225}Pa decay spectroscopy

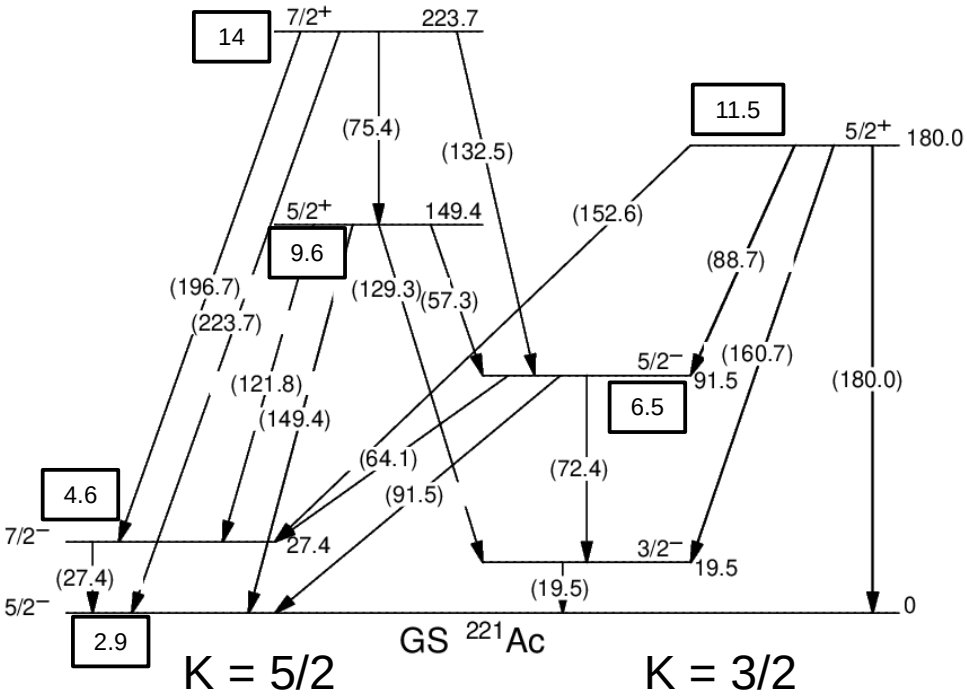


^{221}Ac level scheme

^{225}Pa decay spectroscopy

Hindrance factor:

$$HF = \frac{T_{1/2,\exp}}{T_{1/2,th}}$$



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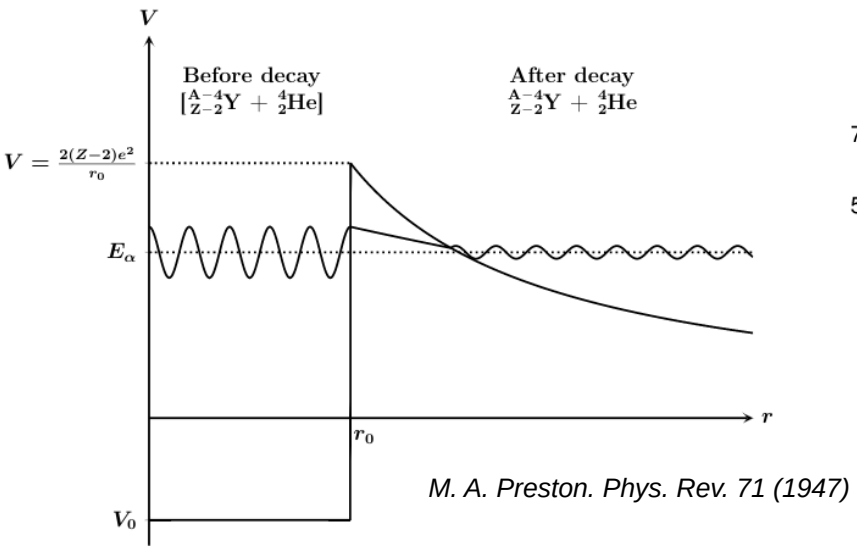
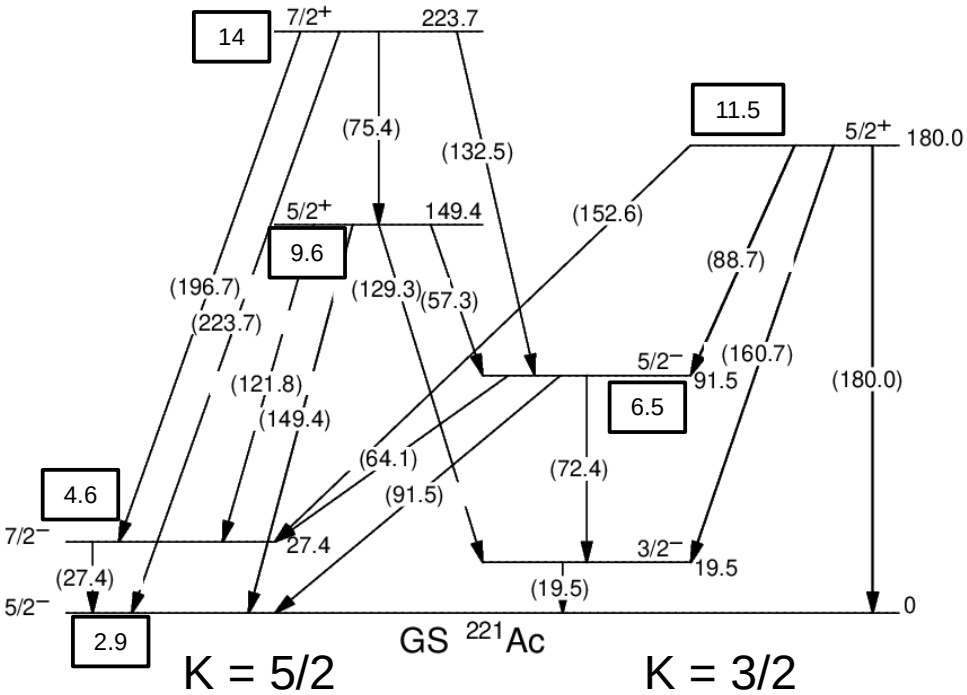


M. A. Preston. Phys. Rev. 71 (1947)



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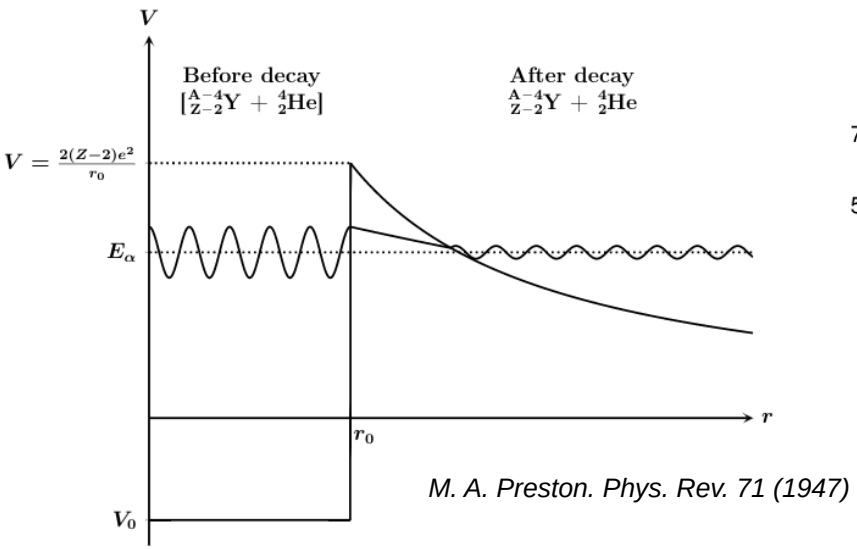

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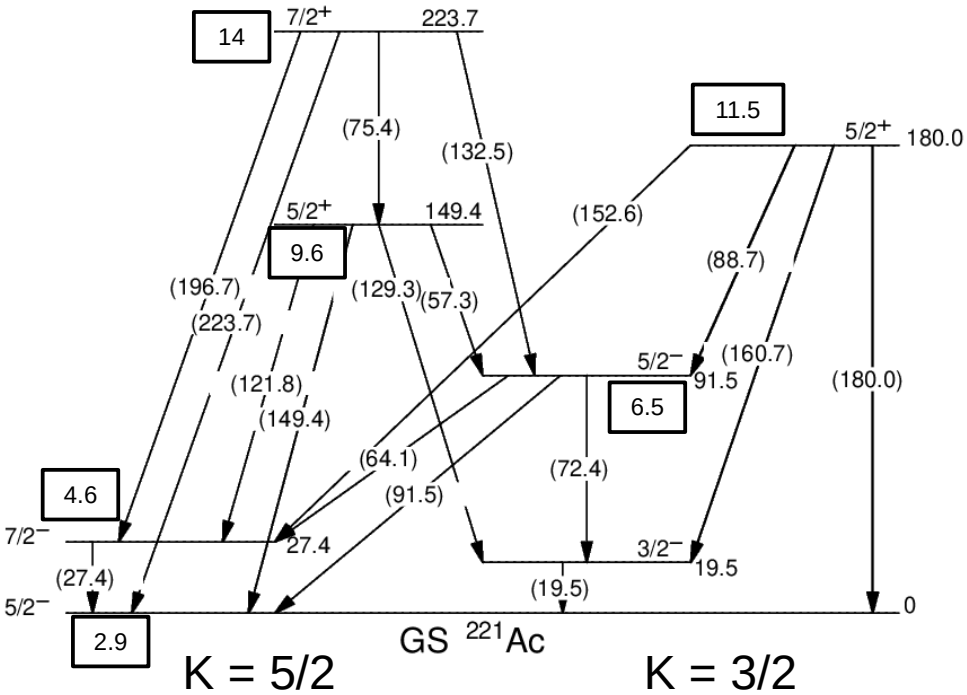

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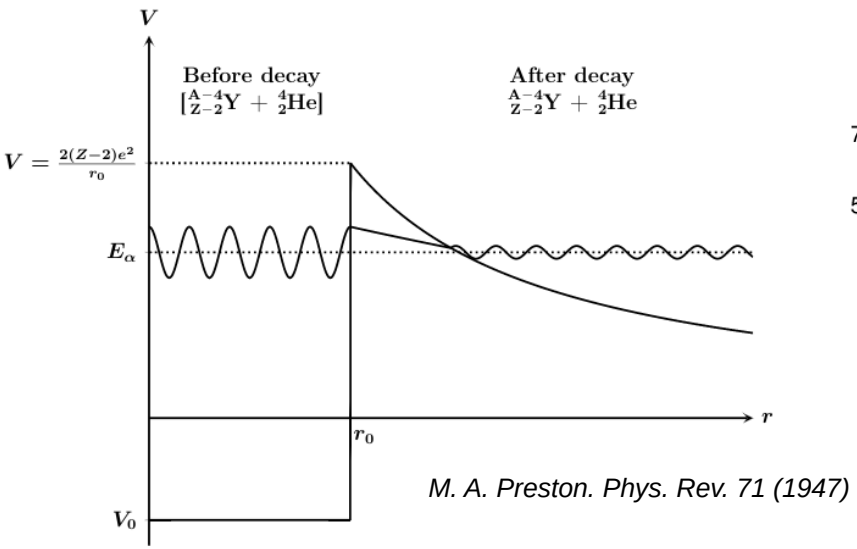

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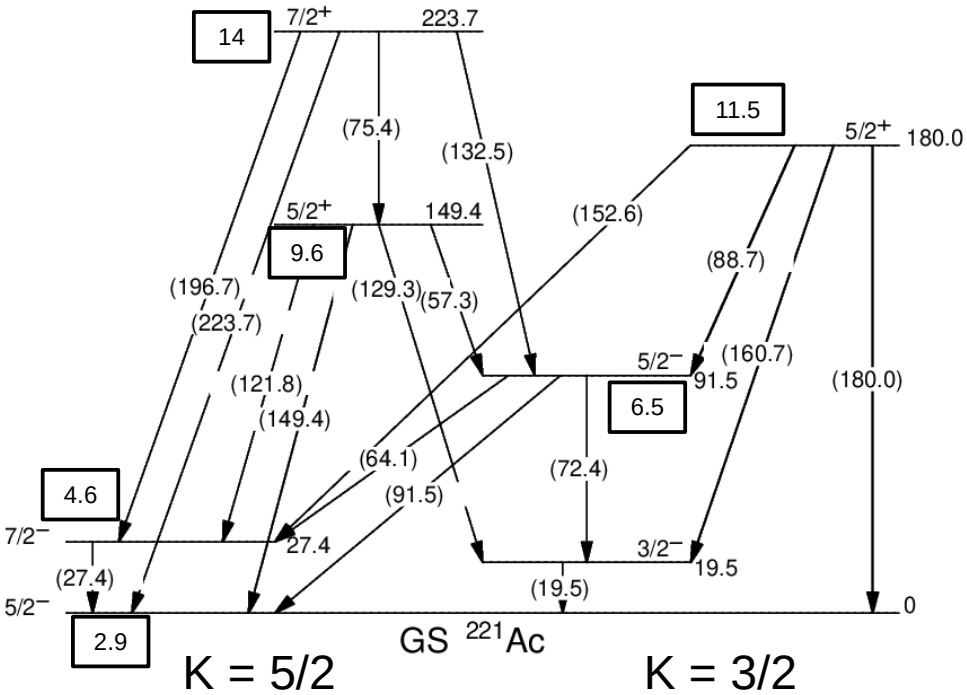

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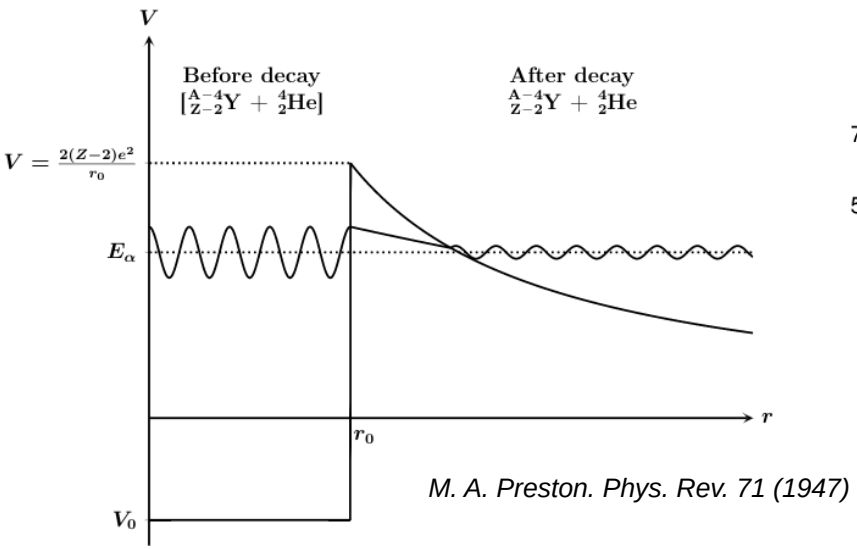

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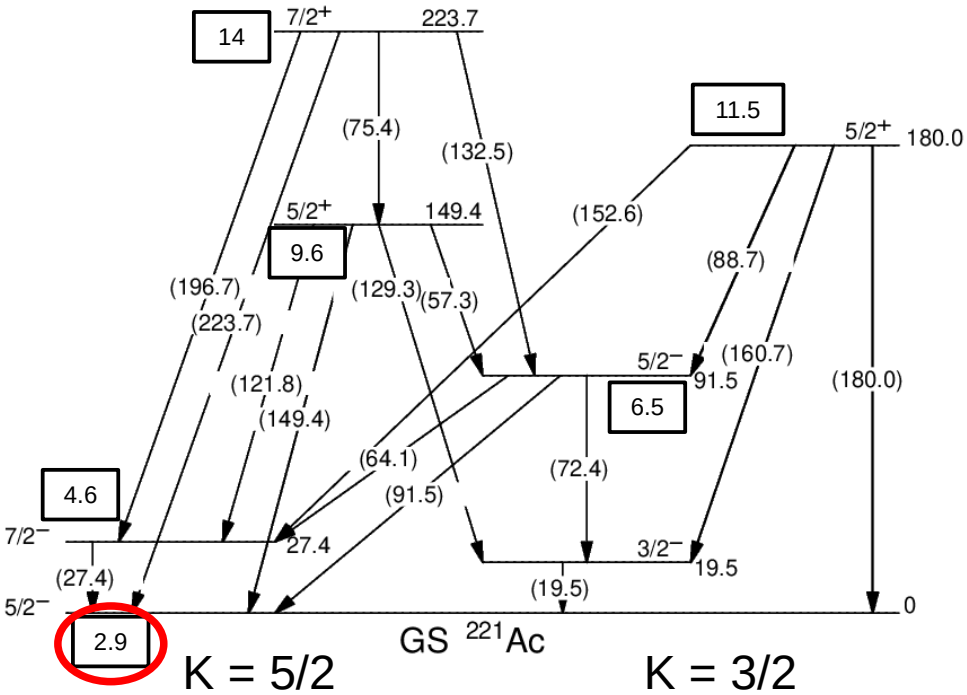

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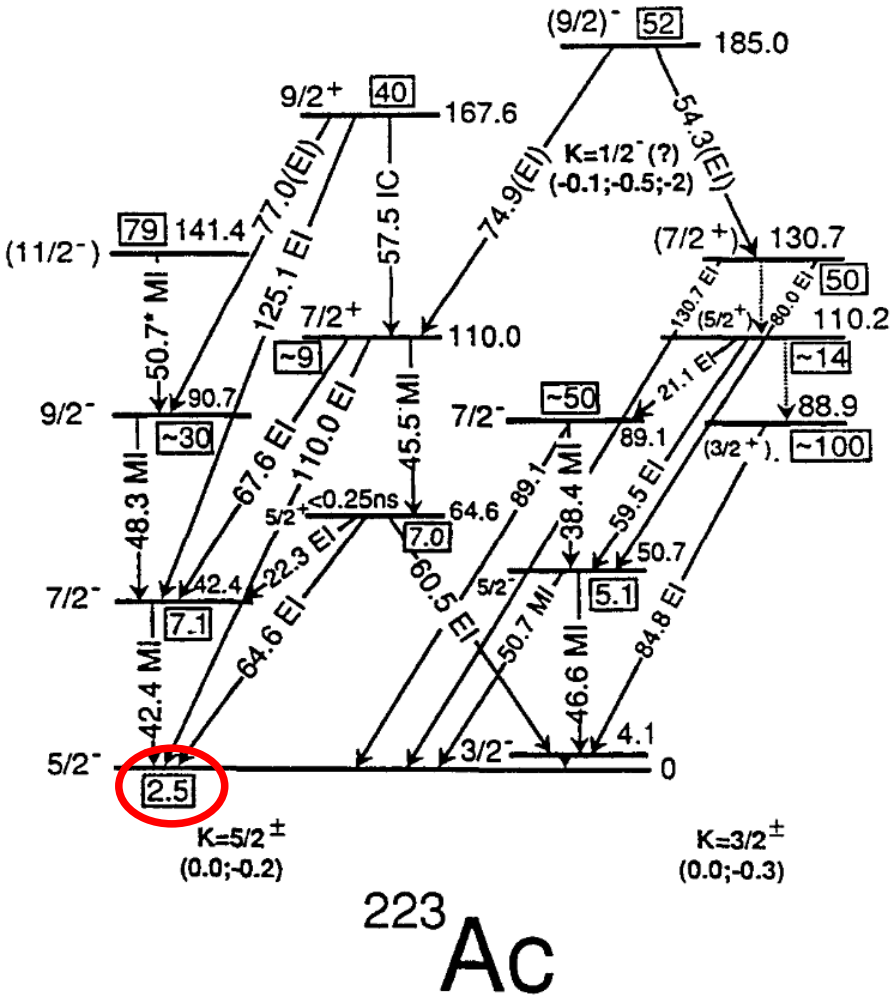

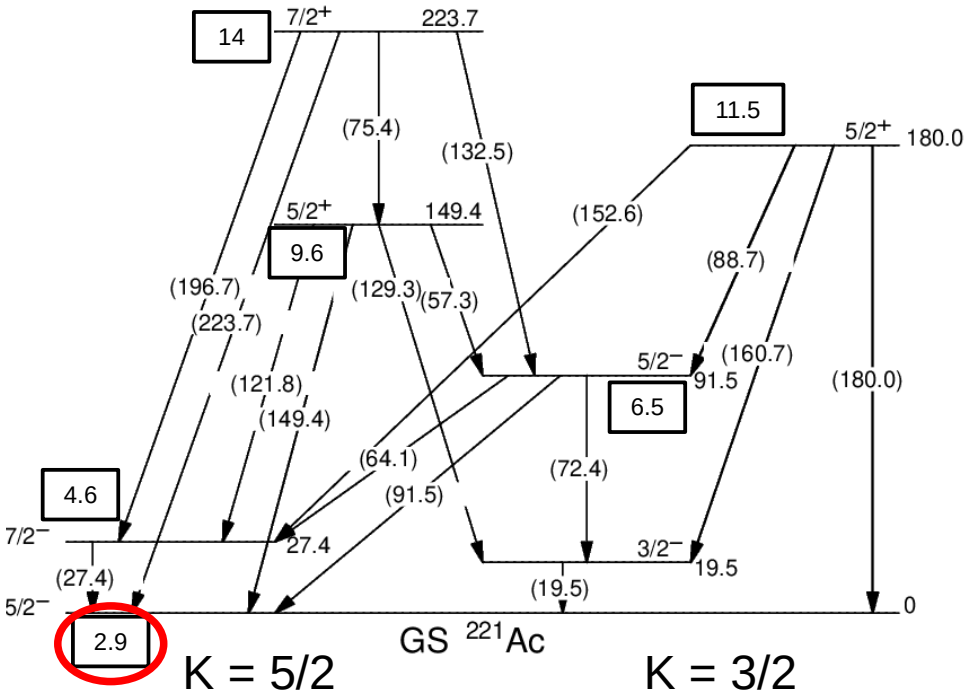

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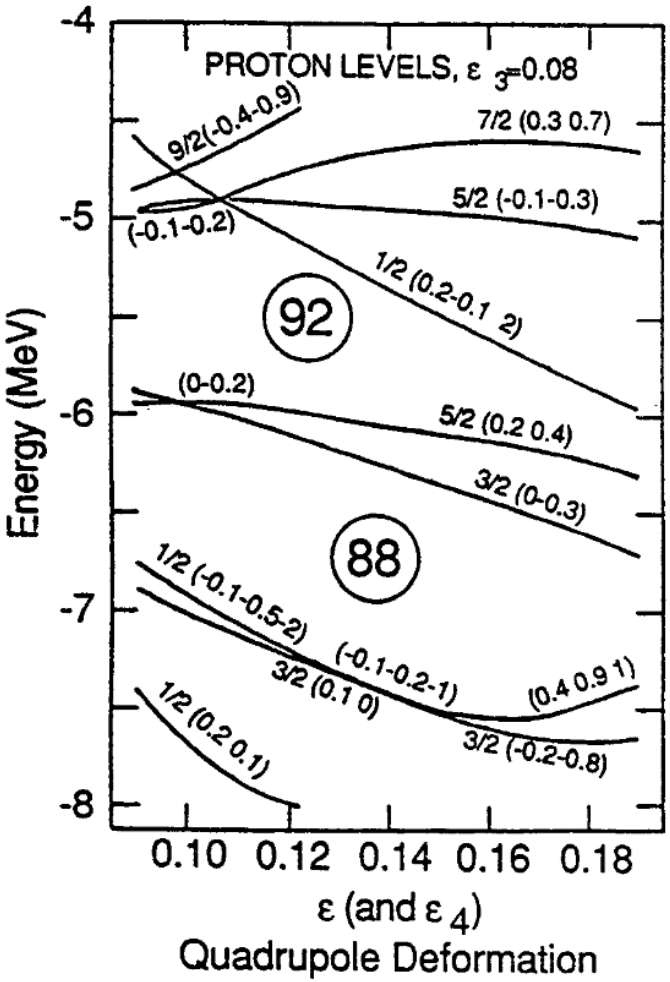

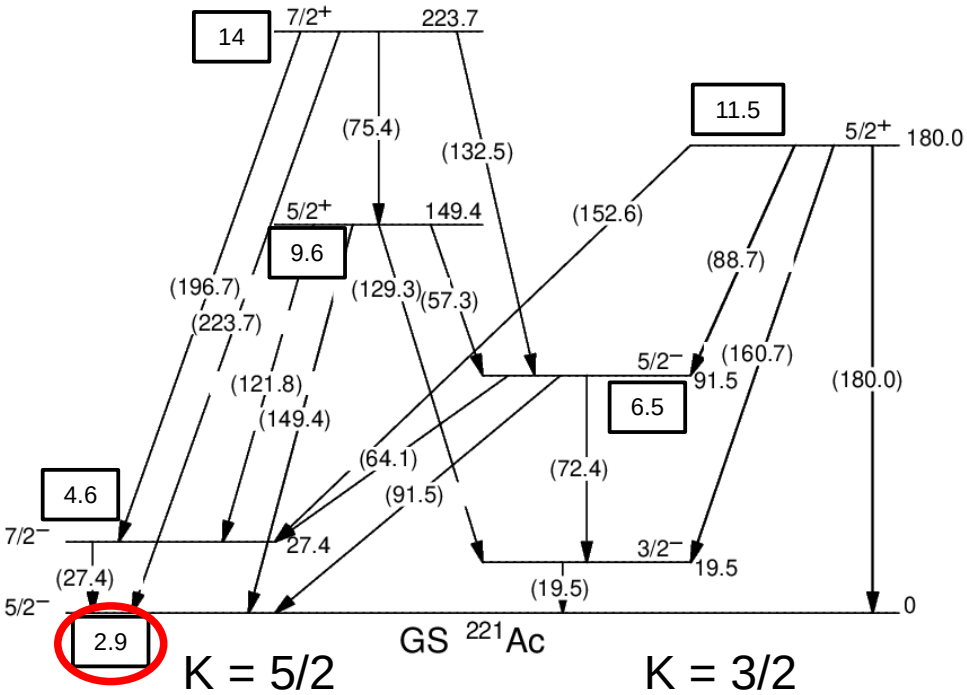

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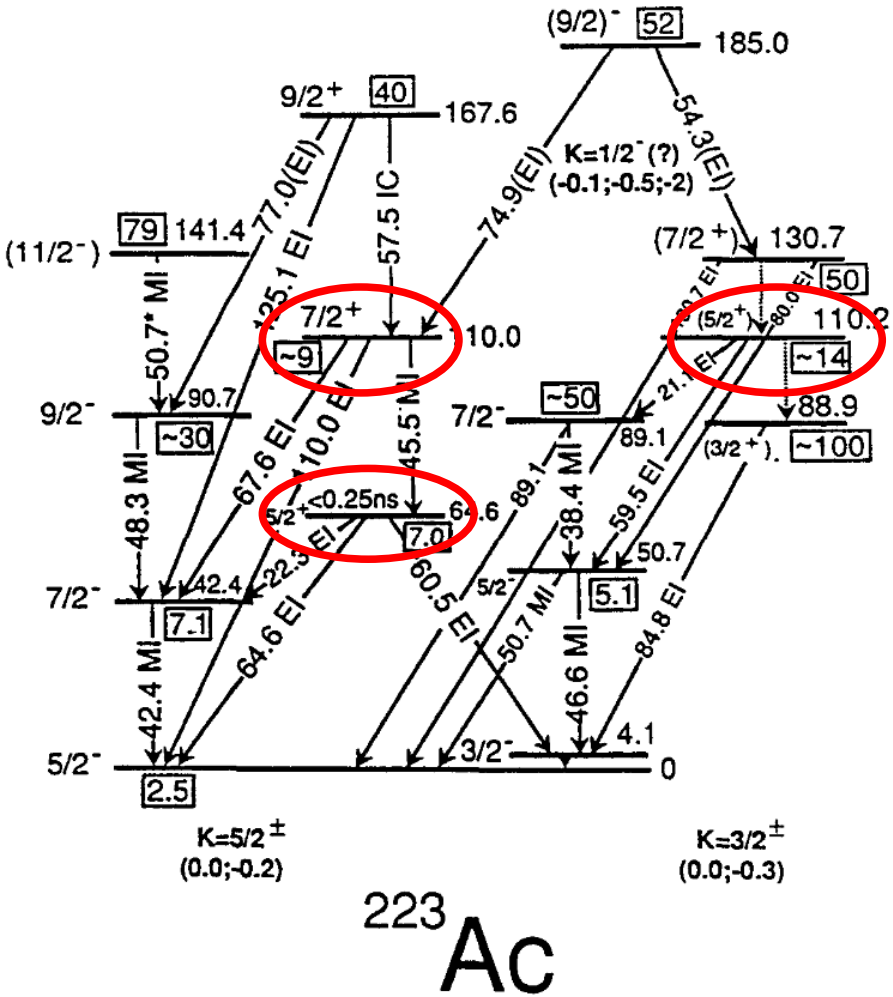

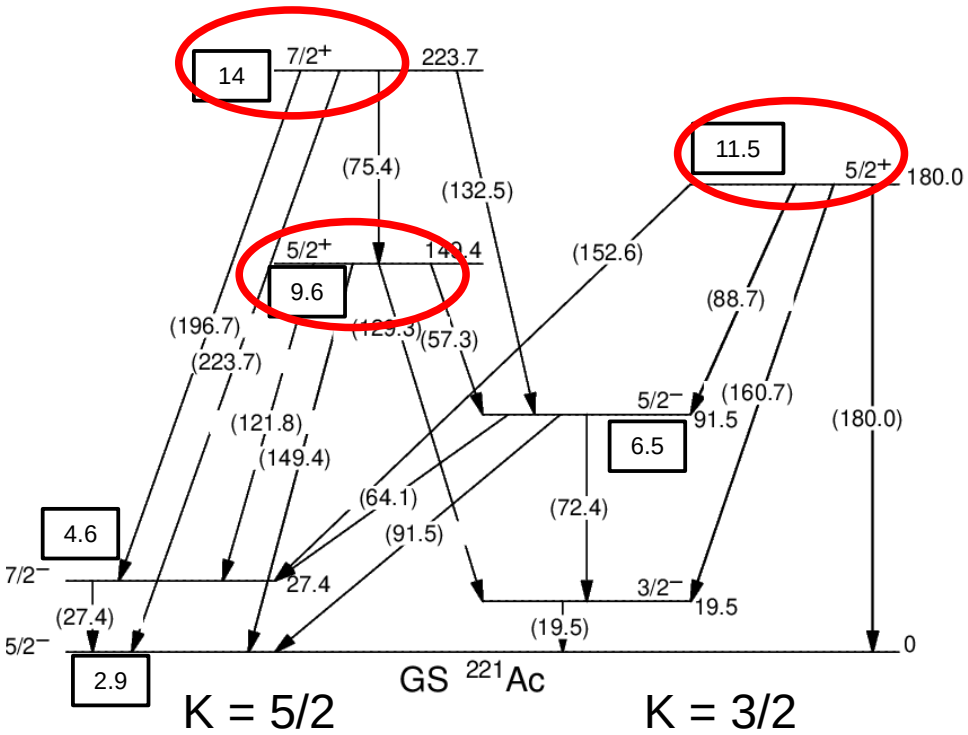

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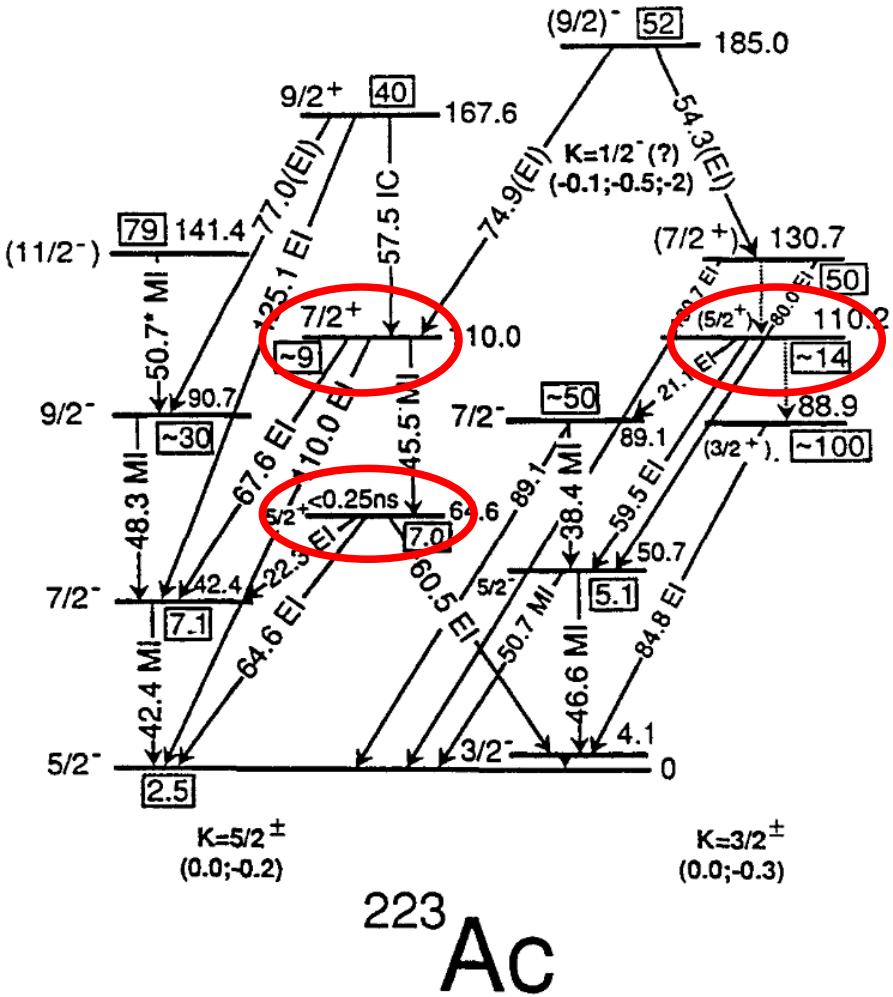

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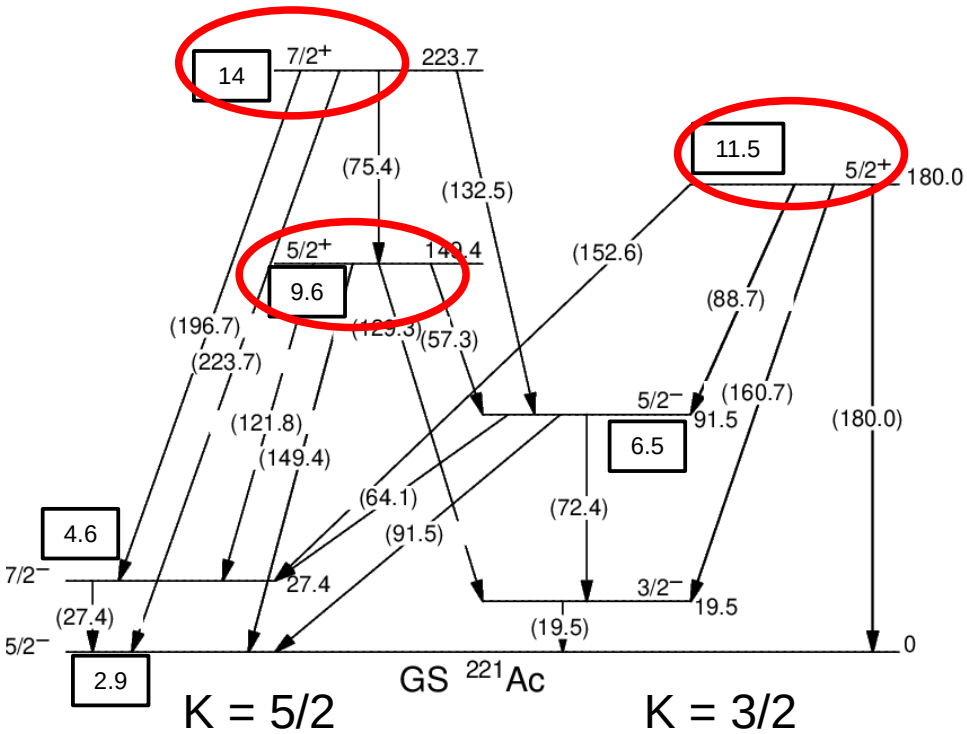
^{221}Ac → Static octupole deformation



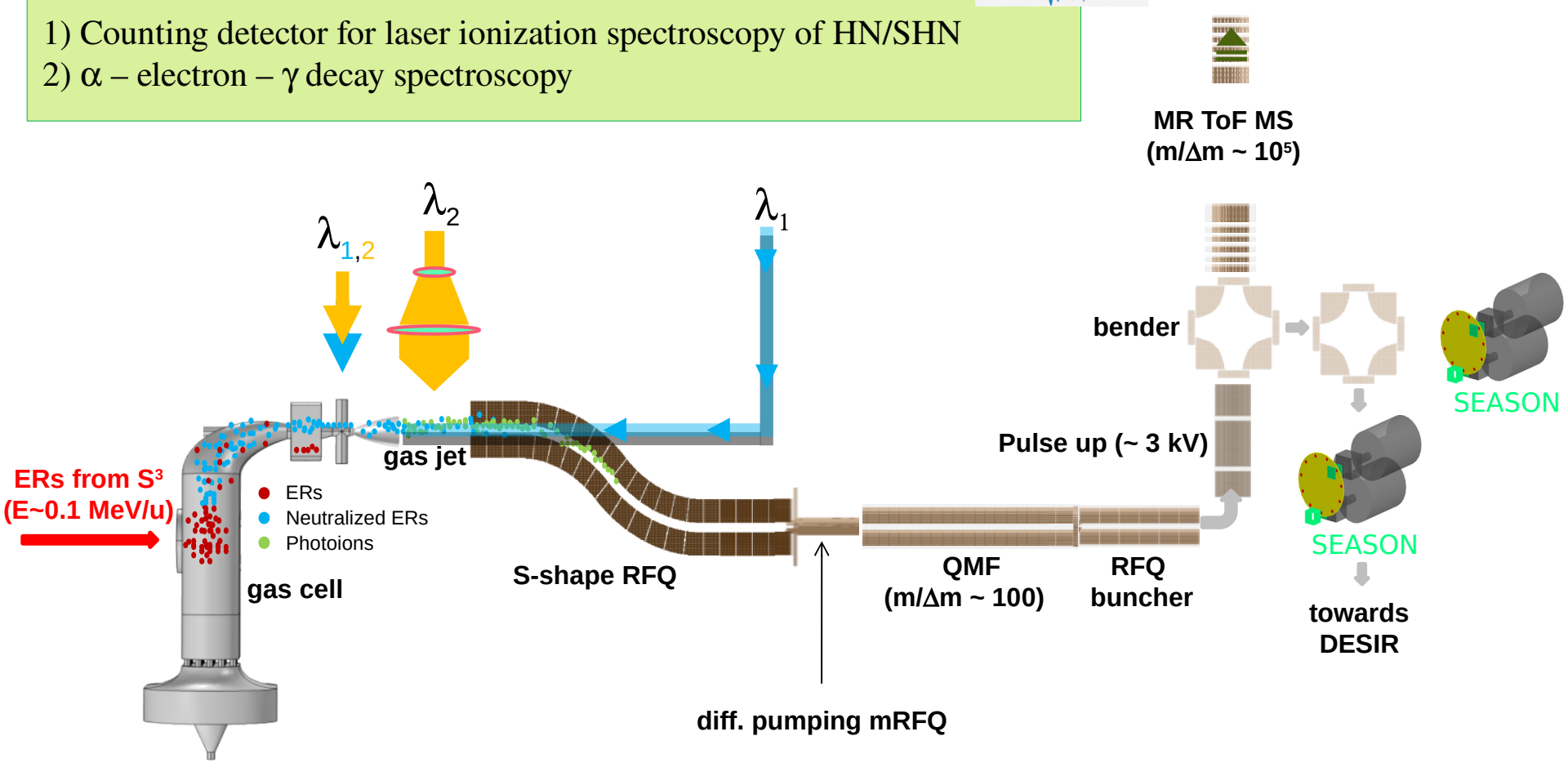
^{221}Ac level scheme

Submitted to PRC

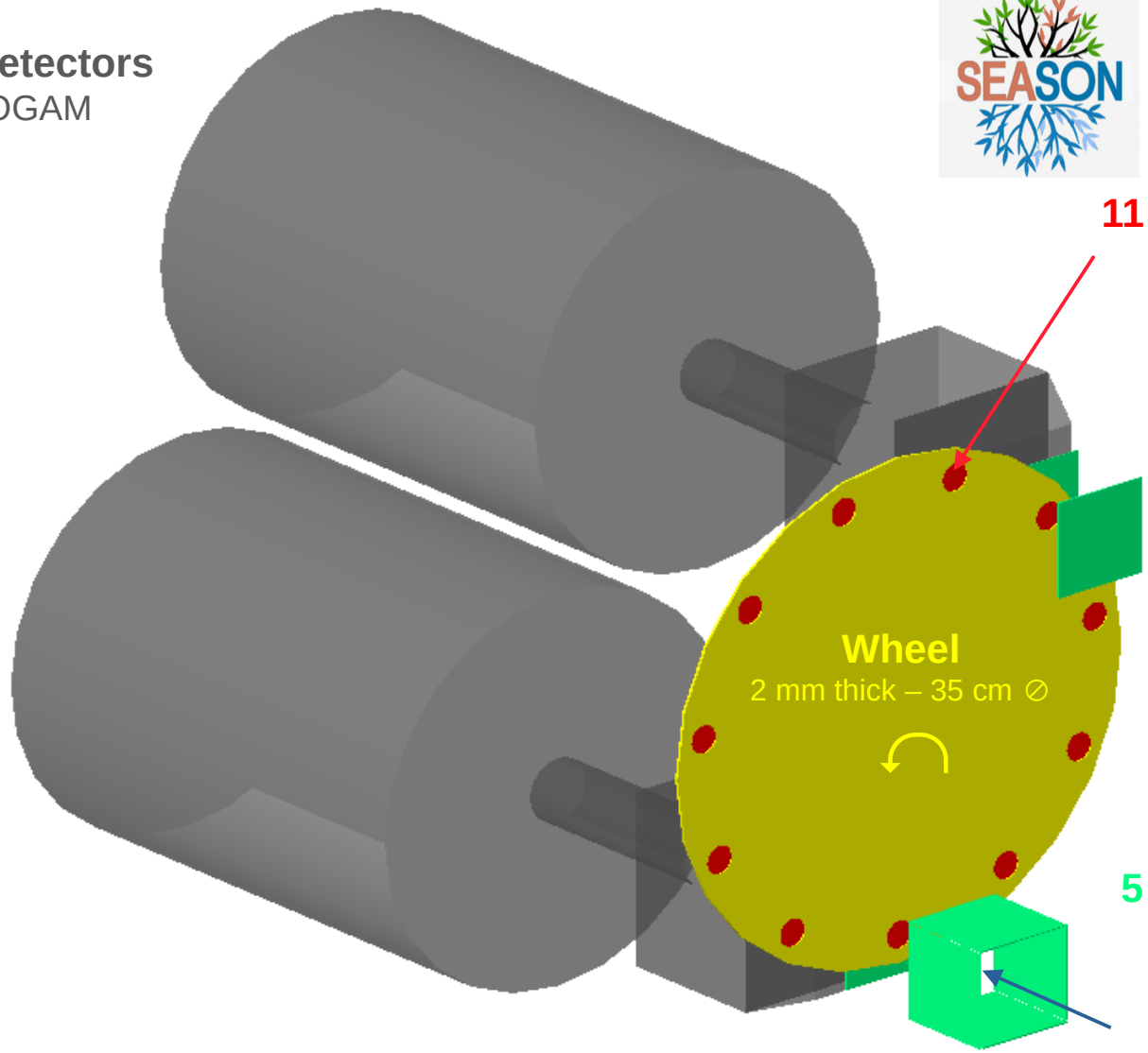
SEASON detector at S³ – LEB (GANIL)

SEASON
(Spectroscopy Electron Alpha in Silicon bOx couNter)

1) Counting detector for laser ionization spectroscopy of HN/SHN
2) α – electron – γ decay spectroscopy



SEASON design



Conclusion and perspectives

Production of ^{225}Pa using the ^{232}Th(p,8n)^{225}Pa reaction at IGISOL, Jyväskylä

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SEASON @S3-LEB : Exploration of more exotic neutron-deficient actinides

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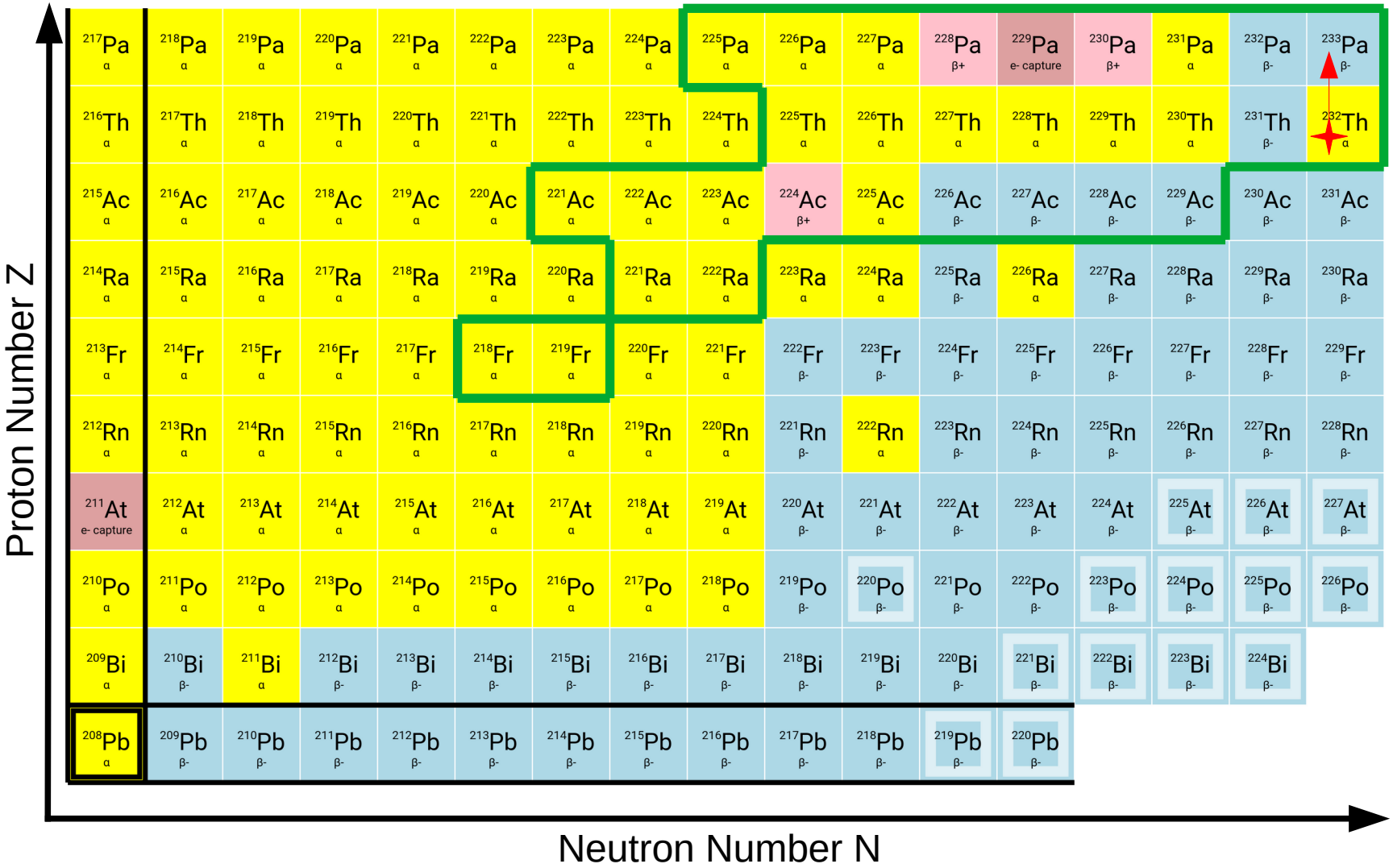
SEASON @S3-LEB : Exploration of more exotic neutron-deficient actinides

Thank you for your attention !

Backup

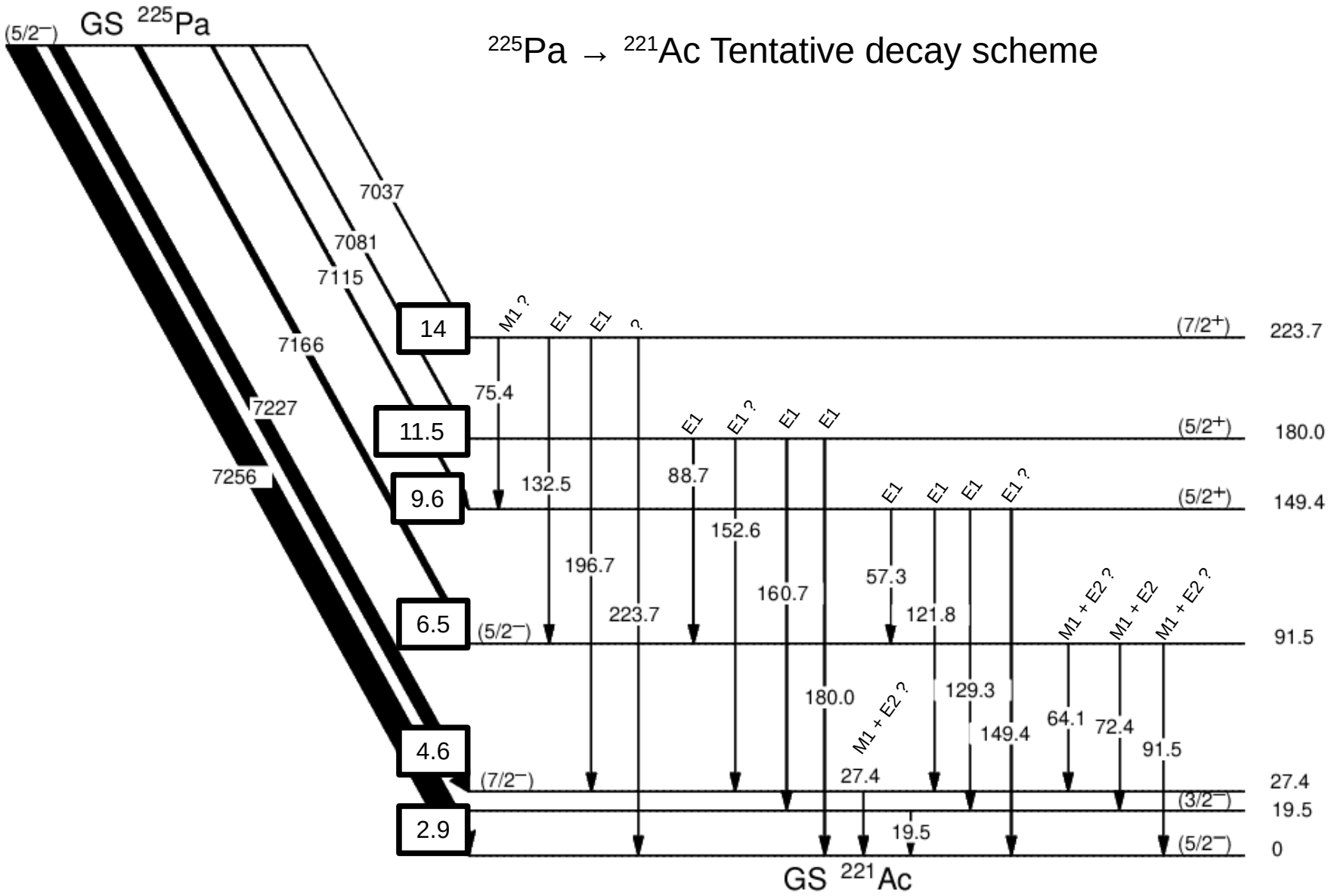
Production method

Proton induced fusion-evaporation reaction ^{232}Th(p,x)Y at IGISOL

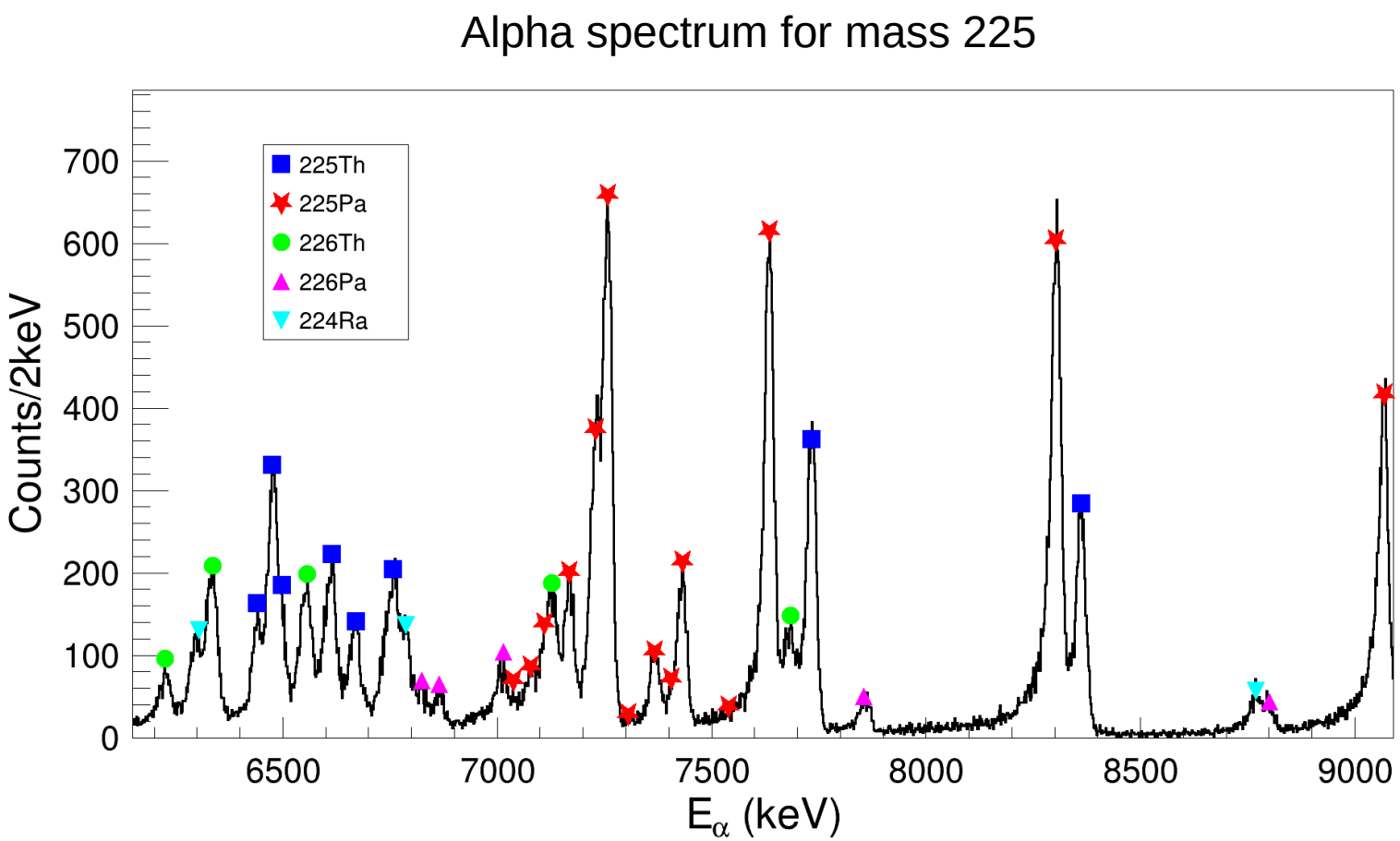


Data analysis for mass 225

$^{225}Pa \rightarrow {}^{221}Ac$ Tentative decay scheme



^{225}Pa decay spectroscopy – Preliminary results



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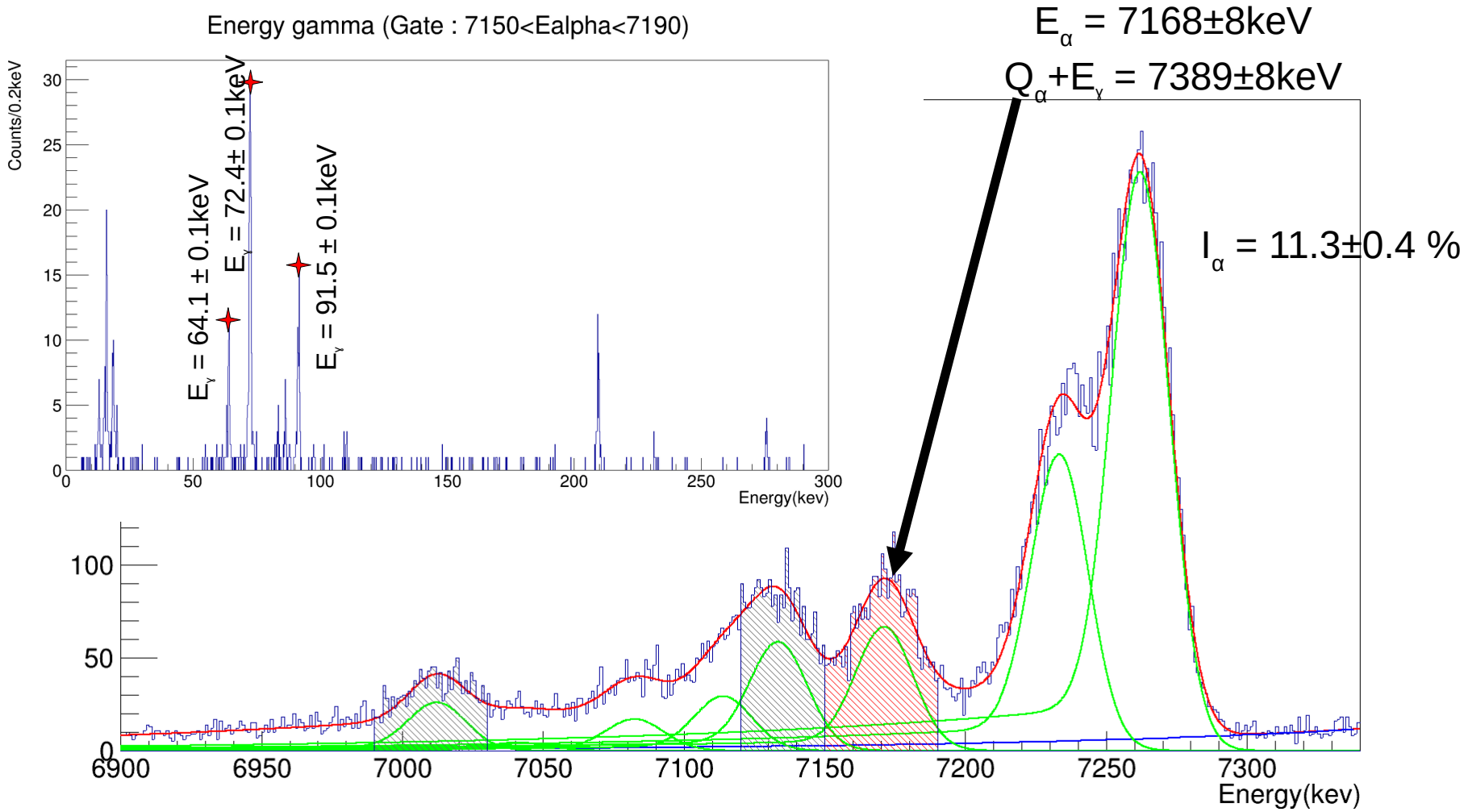

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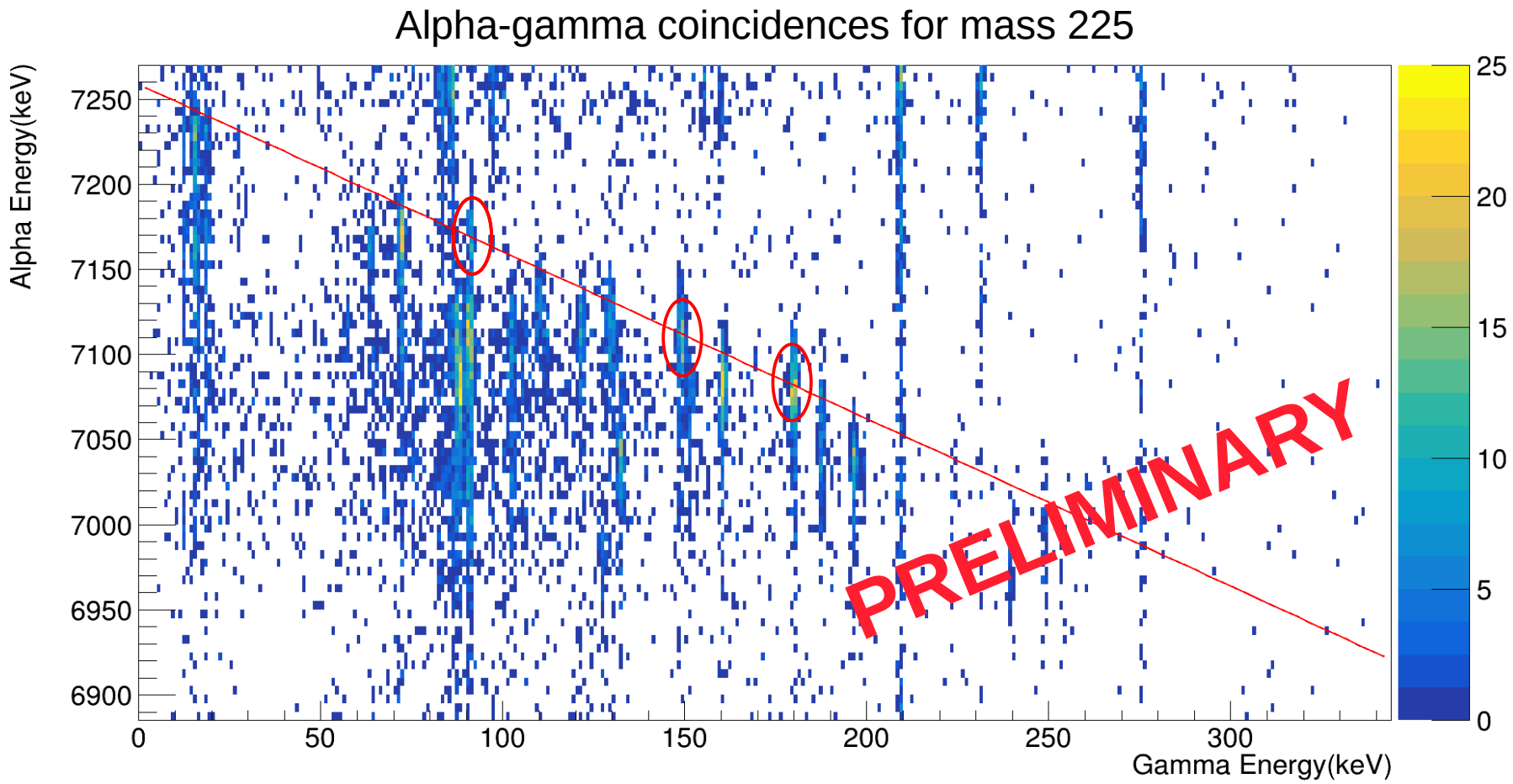
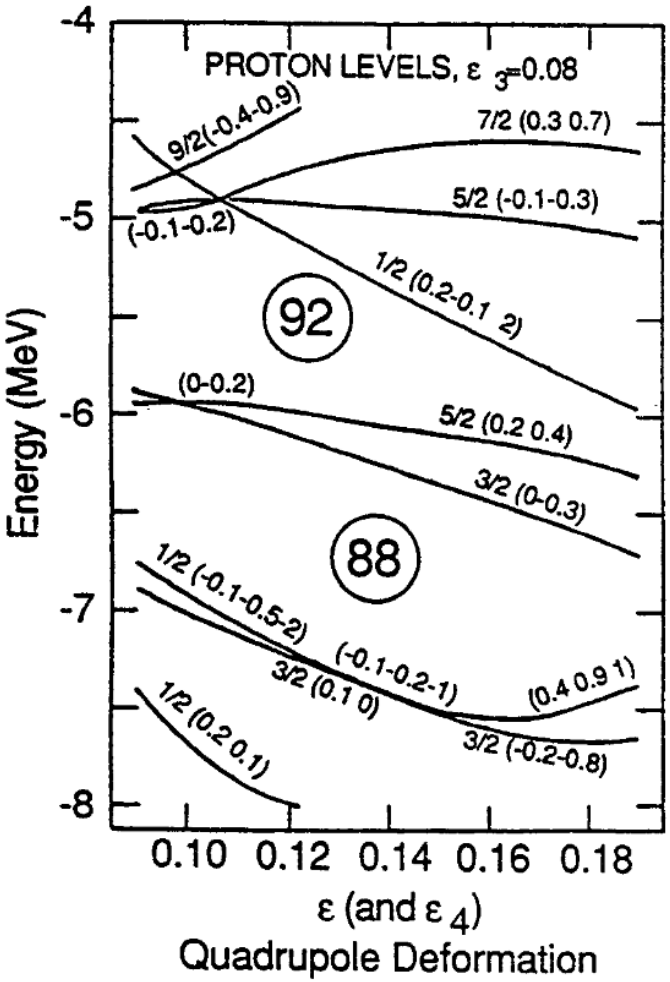
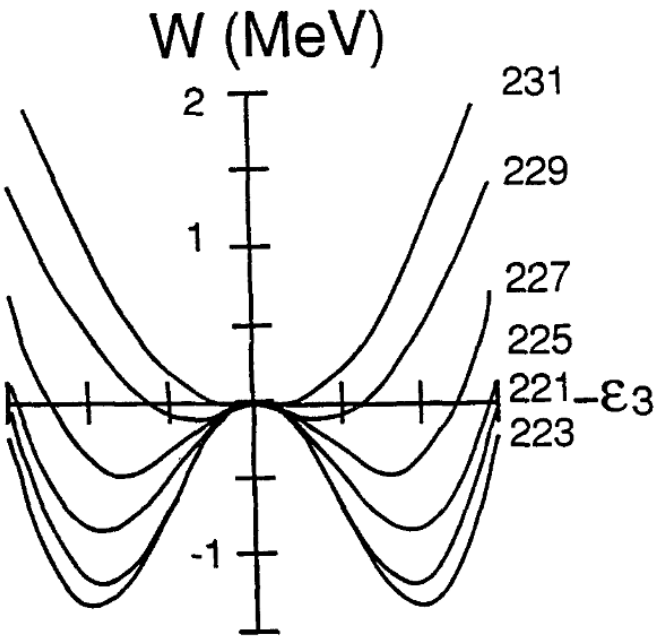


Literature for 223Ac





Ac :
219 : 9/2-
221 : 5/2-
223 : 5/2-
225 : 3/2-
227 : 3/2-

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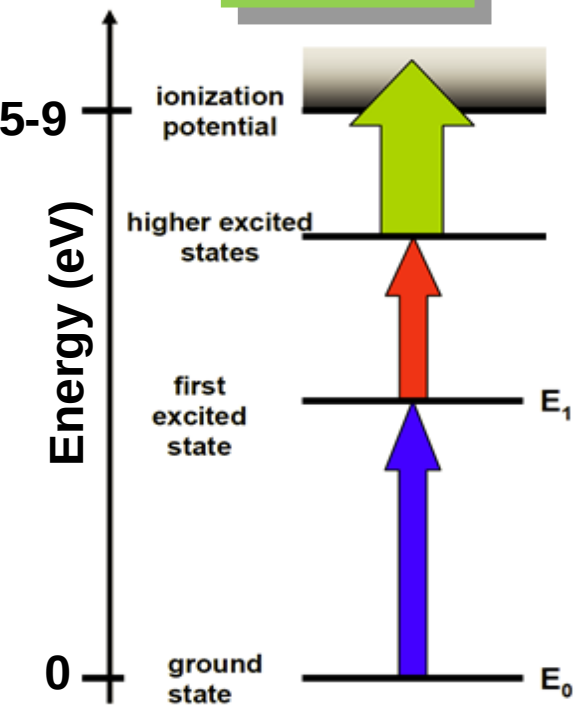
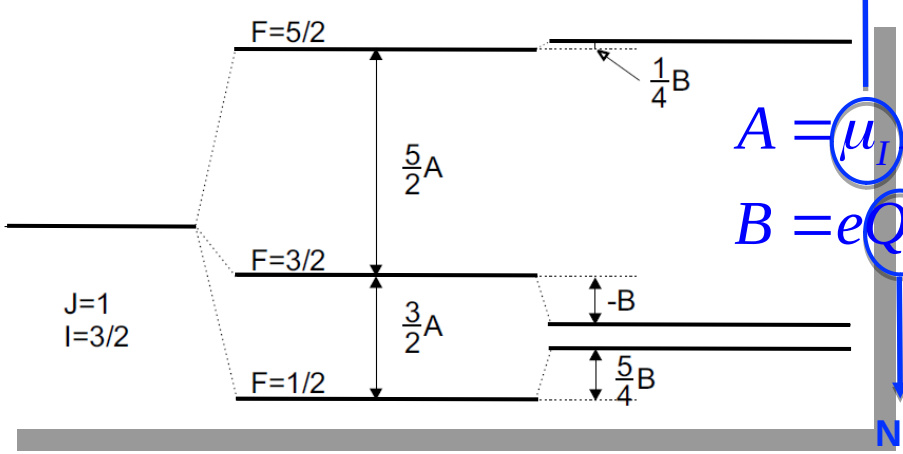
Observables in LIS

Sensitivity



Hyperfine Splitting



Nuclear magnetic dipole moment

$$A = \mu_I B_e(0)/(IJ)$$

$$B = eQ_S V_{ZZ}(0)$$

Nuclear electric quadrupole moment

Isotope Shift

$$\delta\nu_{\mathrm{IS}}^{AA'} = K_{\mathrm{MS}} \cdot \frac{M_{A'} - M_A}{M_A M_{A'}} + \frac{2\pi Z e}{3} \Delta\,|\Psi(0)|^2\ \delta\left\langle r^2 \right\rangle^{AA'}$$

Charge radii