

Low-lying states in ^{219}Ra and ^{215}Rn : sampling microsecond α -decaying nuclei

*Knut och Alice
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On behalf of the
TASCA E115 Collaboration

May 9, 2018

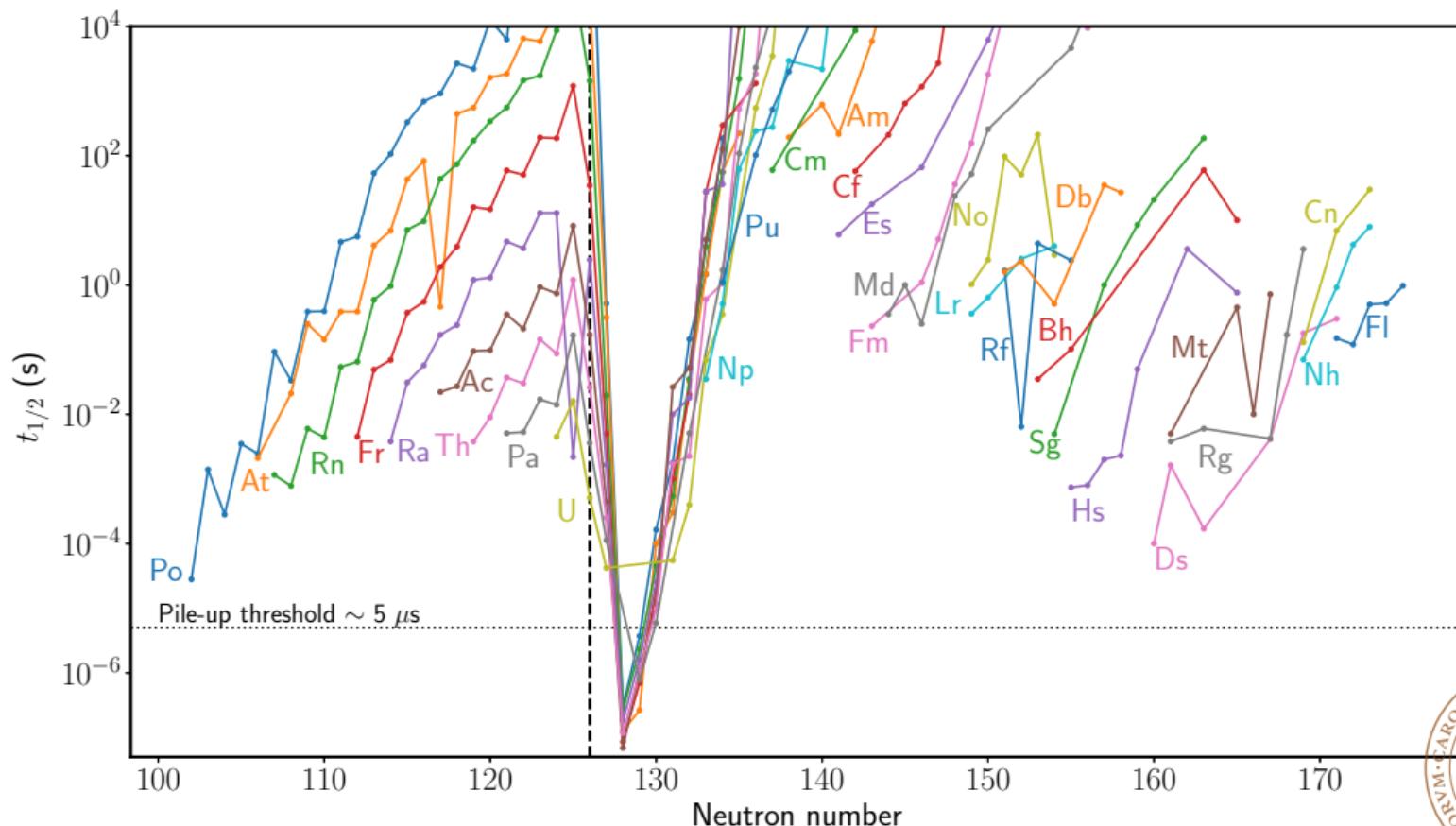


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Outline

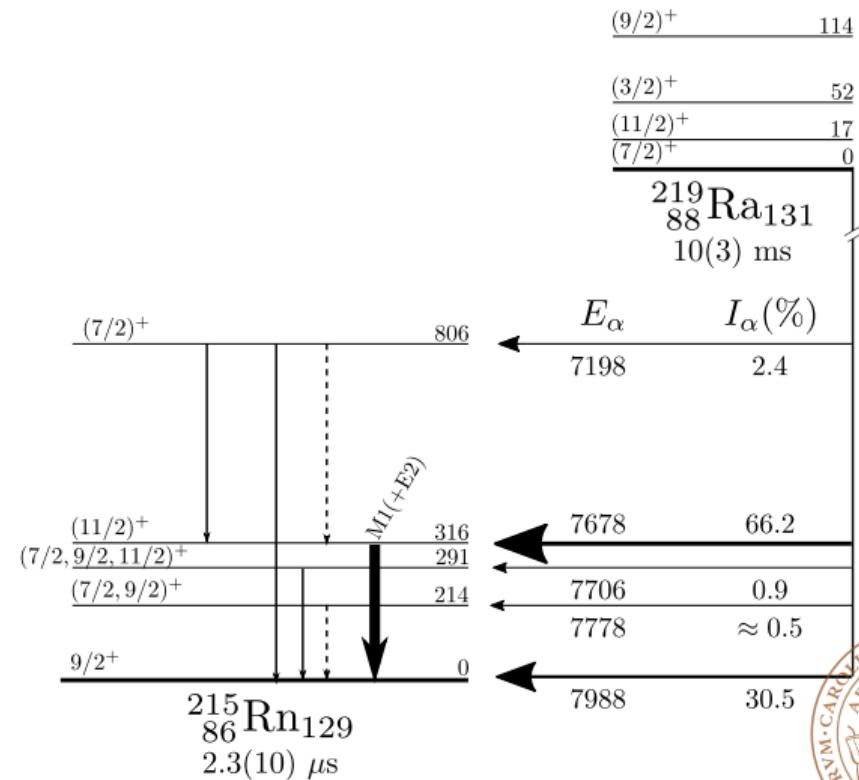
- 1 Fast α :s
- 2 Correlation analysis
- 3 $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$
- 4 Further decay chains
- 5 Conclusion





Evaluated decay scheme of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$

- Decay spectroscopy experiments performed:
1970 [1], 1987 [2] & 1994 [3].
- Angular correlation measurement 1989 excluded $I^\pi = 9/2$ for ^{219}Ra ground state [4].



[1] K. Valli, et al., Phys. Rev. C. **1**, 6 (1970).

[2] A. M. Y. El-Lawindy et al., J. Phys. G: Nucl. Phys., (1987).

[3] R. K. Sheline, et al., Phys. Rev. C. **49**, 2 (1994).

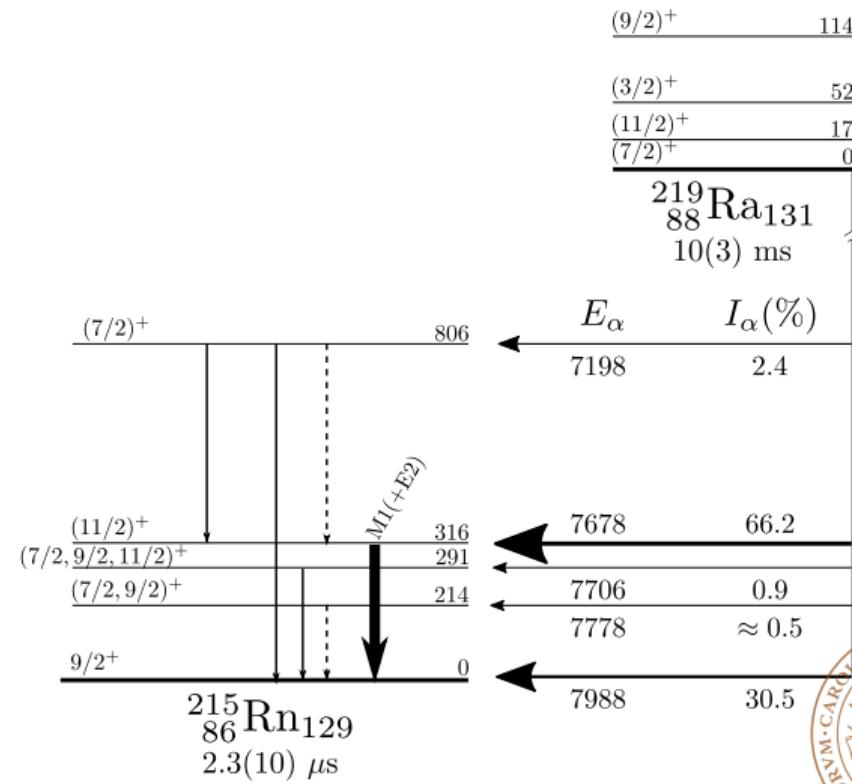
[4] E. D. Hackett, et al., Phys. Rev. C. **40**, 1234 (1989).



Evaluated decay scheme of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$

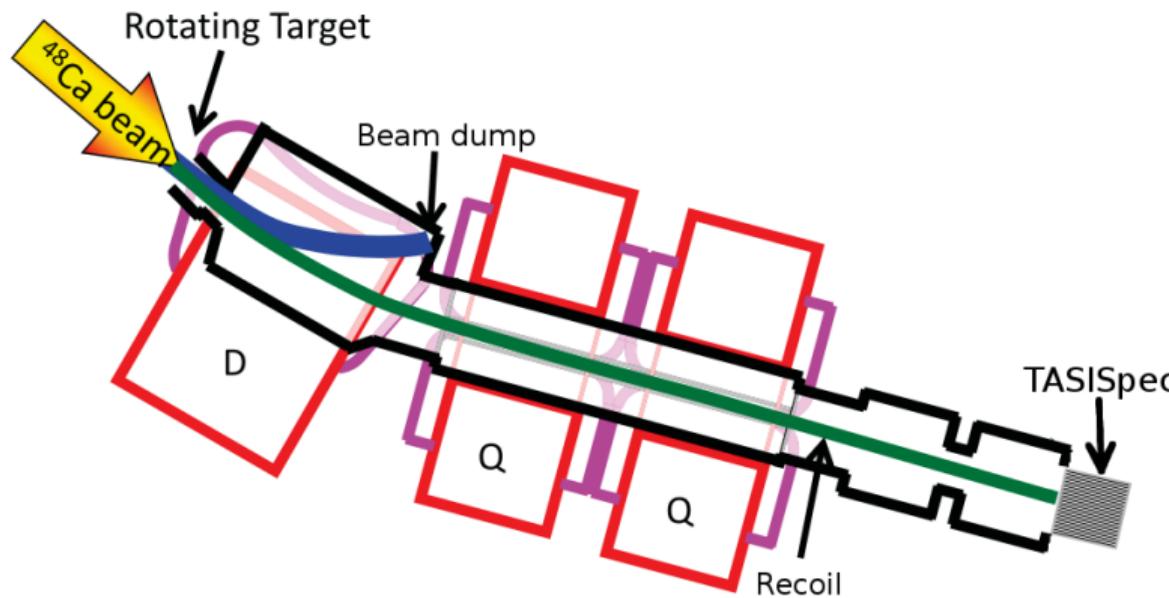
- Low lying levels in ^{219}Ra from Riley *et al.* 2000 [5].
- Weisskopf estimate for 17 keV $E2$ transition: 6 ms.
- Main focus: the existence of isomeric α -decaying 17 keV state in ^{219}Ra .

[5] L. A. Riley *et al.*, Phys. Rev. C **62**, 021301(R) (2000).



The 2012 E115-experiment

The reaction: $^{48}\text{Ca} + ^{243}\text{Am} \rightarrow ^{291}\text{Mc}^*$. Here non-fusion product background . . .



TASCA-separator. Source: Phys. Rev. C, 83:054618.



Correlation analysis

Pixel by pixel correlated events

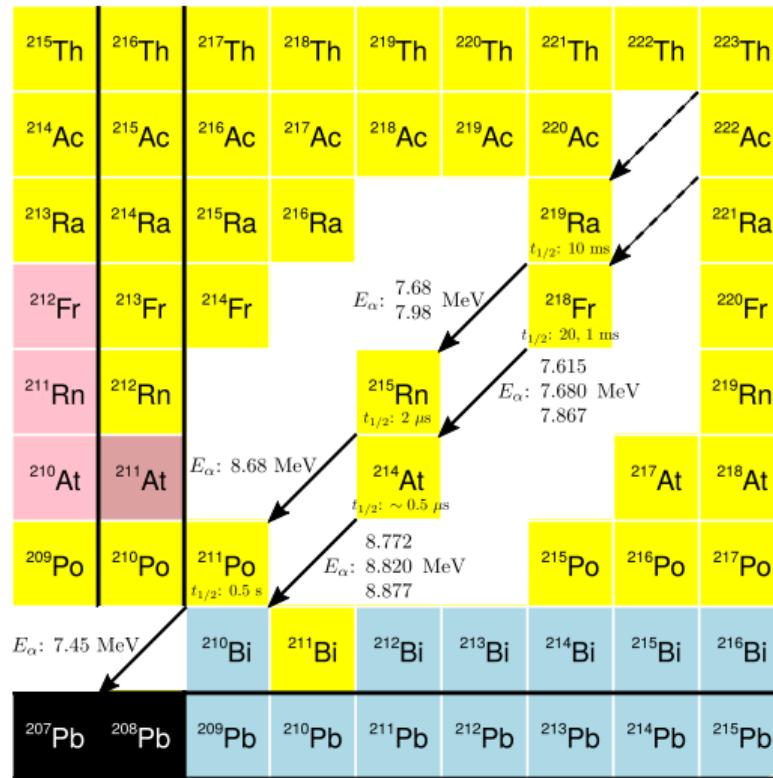
Event

- 1 Pixel
- 2 Time
- 3 Beam ON/OFF
- 4 Silicon detector particle energies
- 5 Germanium detector photon energies

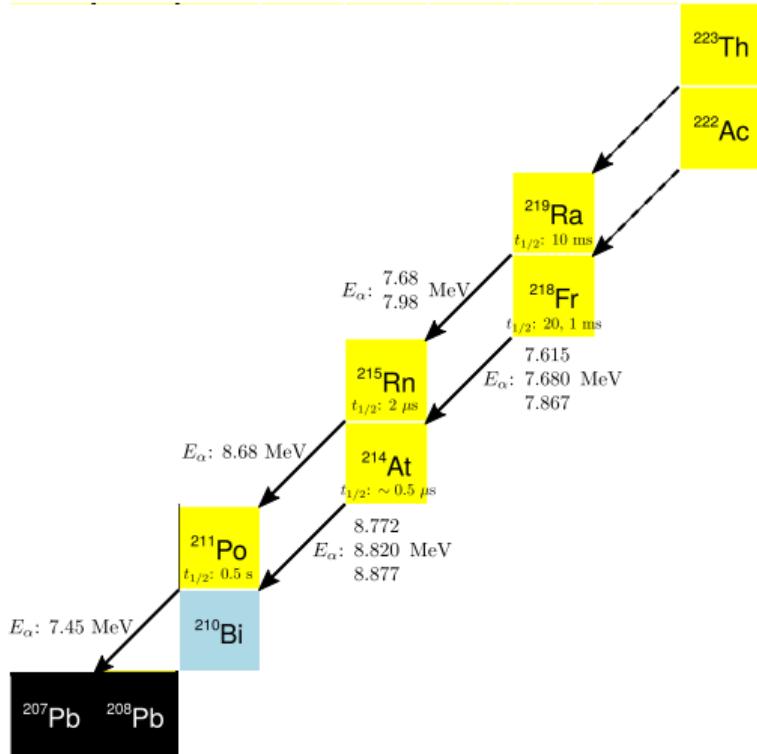
Aim: Select the data for just one decay path, i.e. $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$.



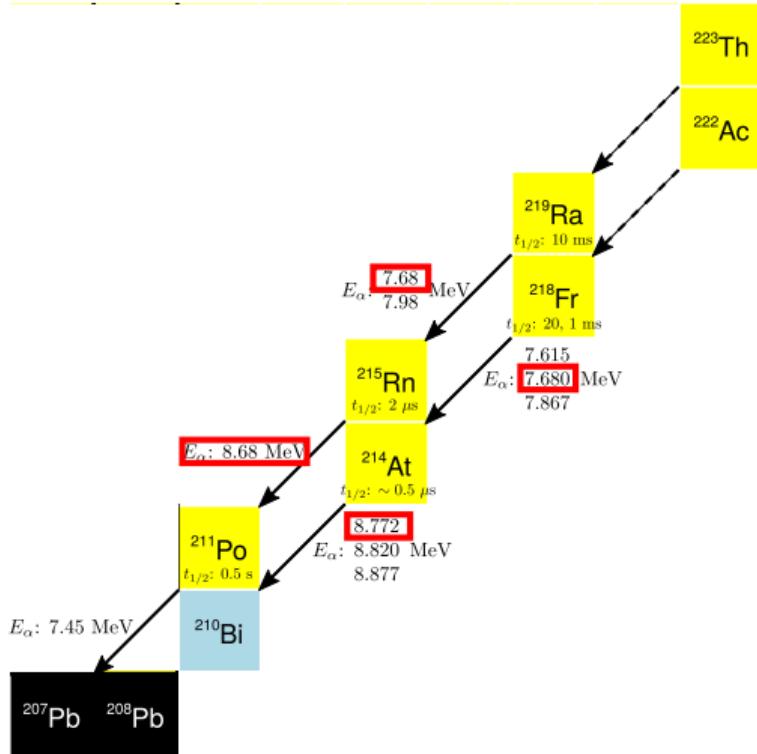
“imp- α_1 - α_2 ” correlated events



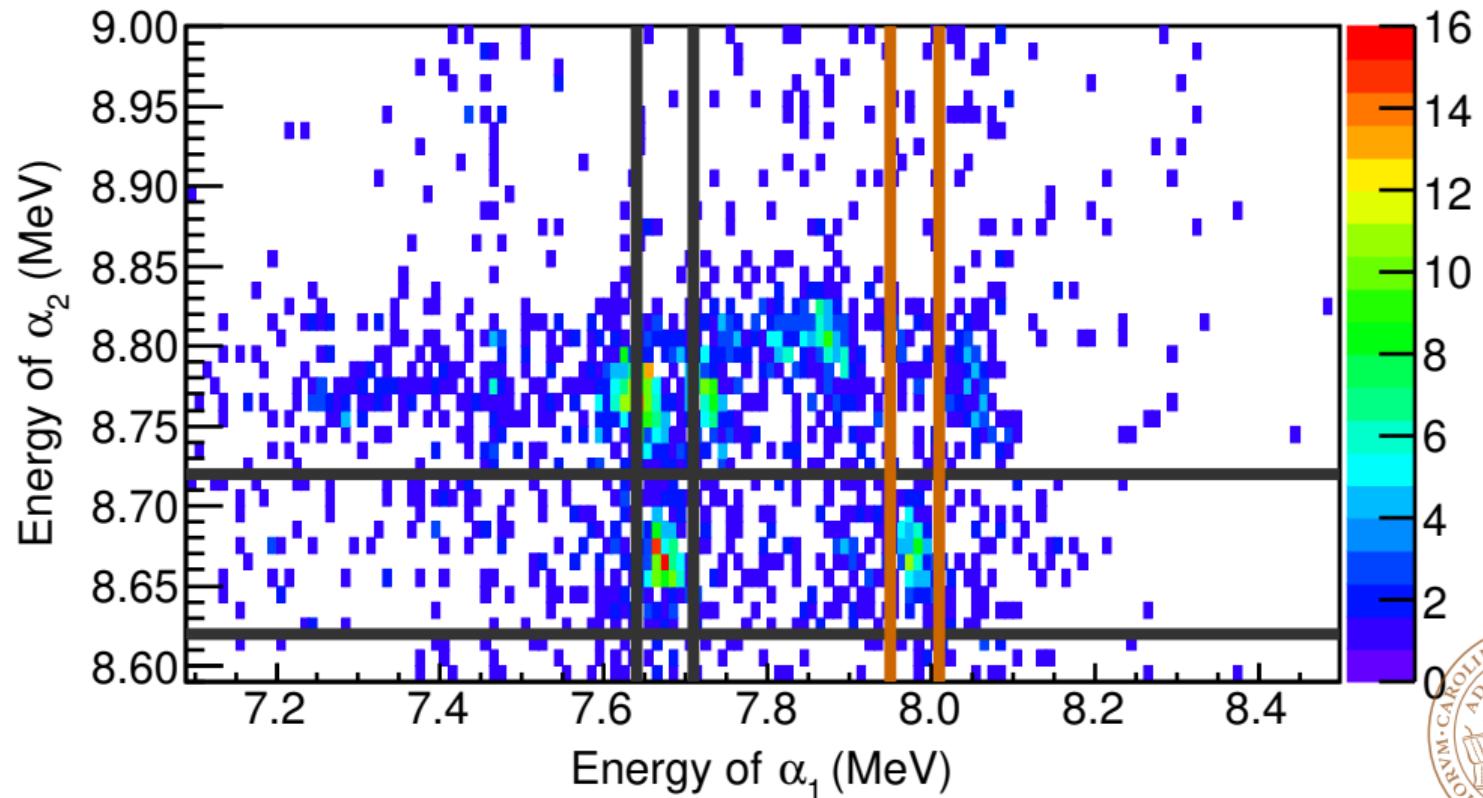
“imp- α_1 - α_2 ” correlated events



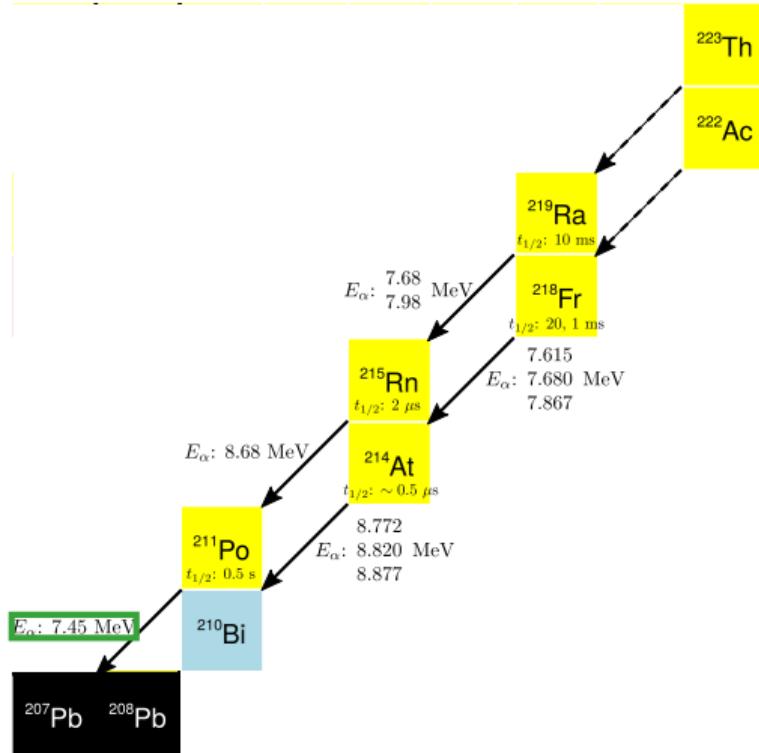
“imp- α_1 - α_2 ” correlated events



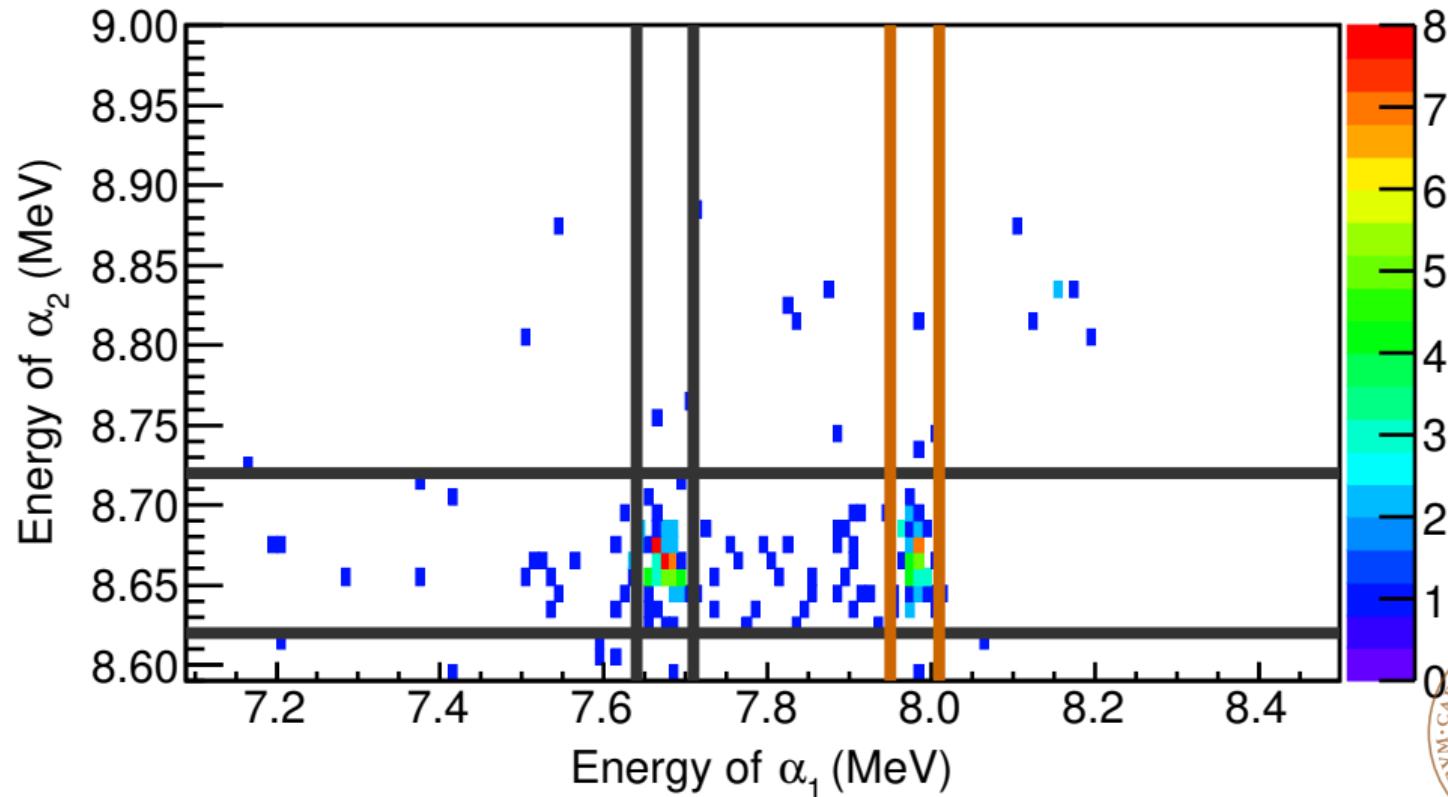
"imp- α_1 - α_2 " correlated events



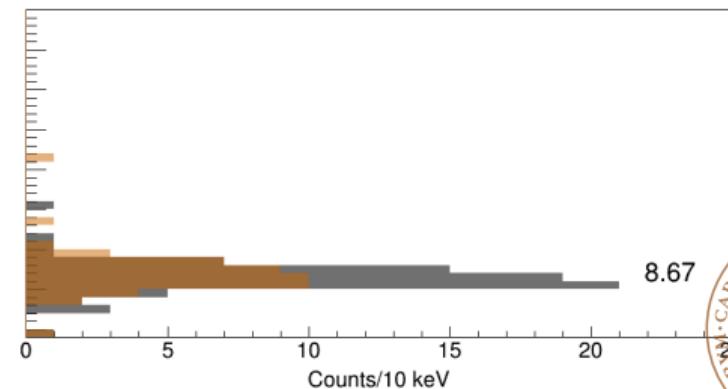
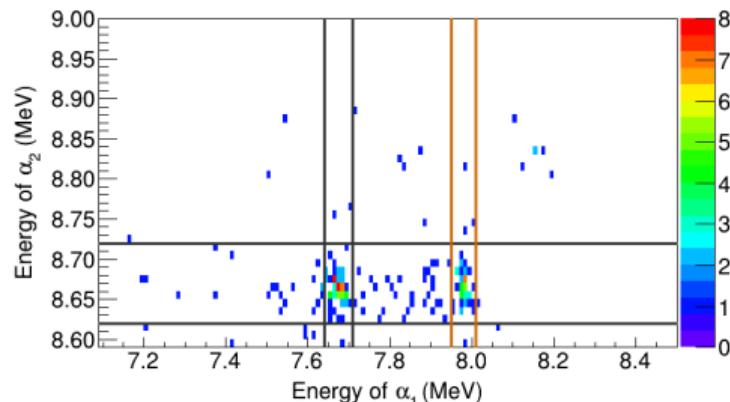
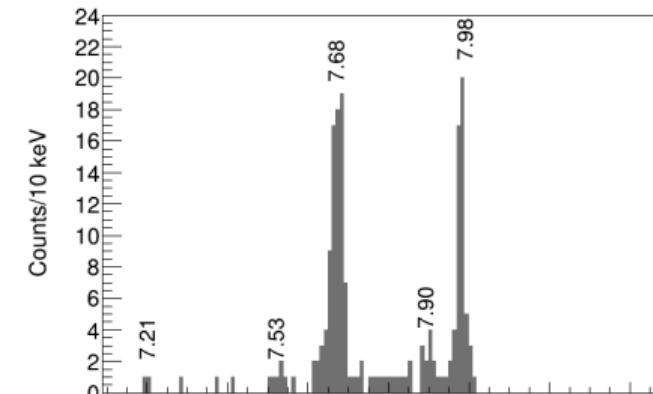
$\text{"}\alpha_1\text{-}\alpha_2\text{-}\alpha_3\text{"}$ correlated events



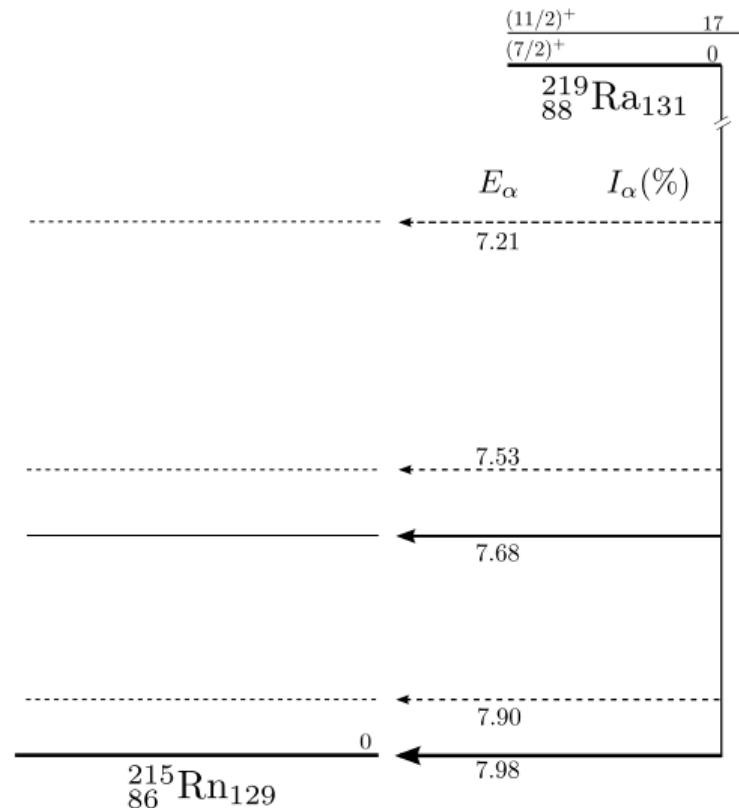
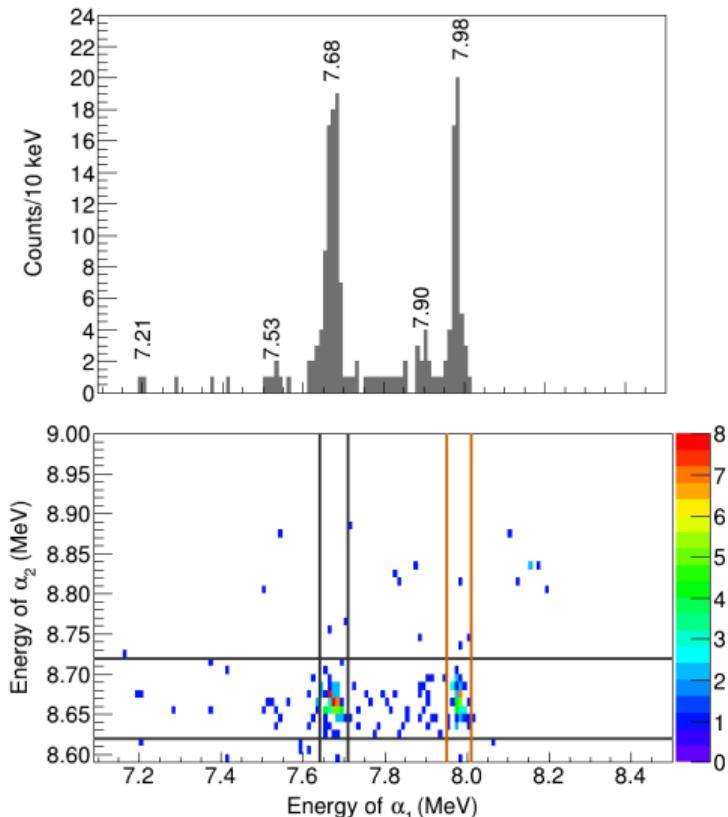
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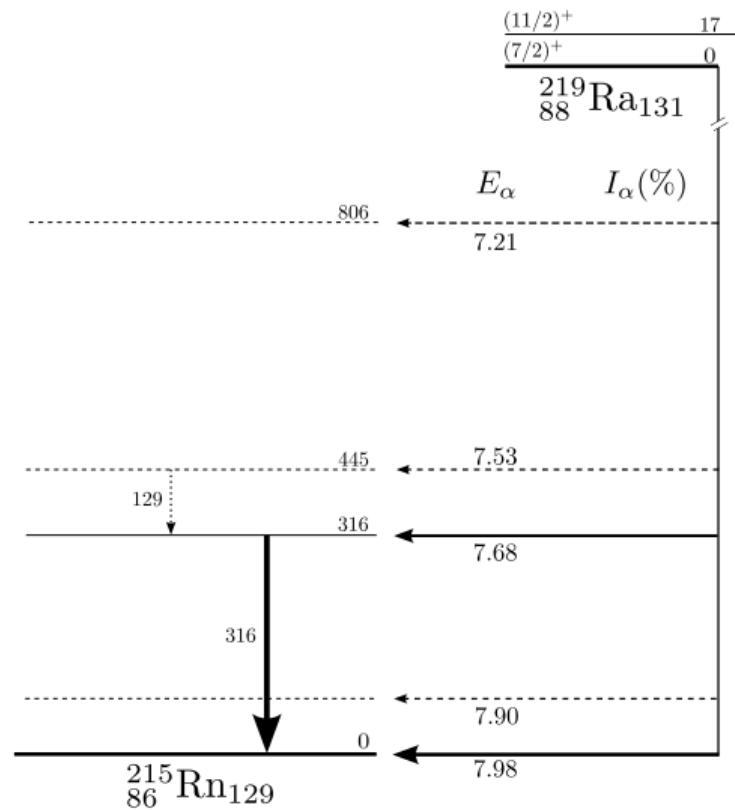
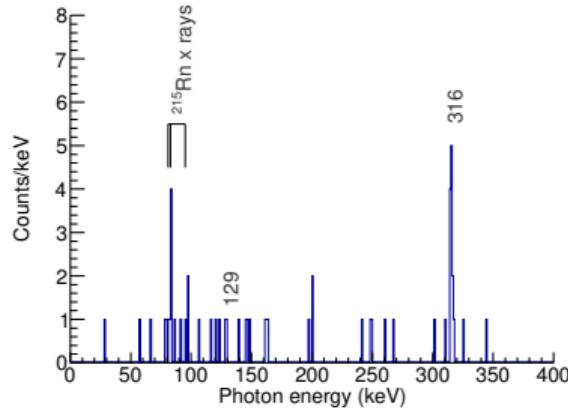
Decay scheme $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$



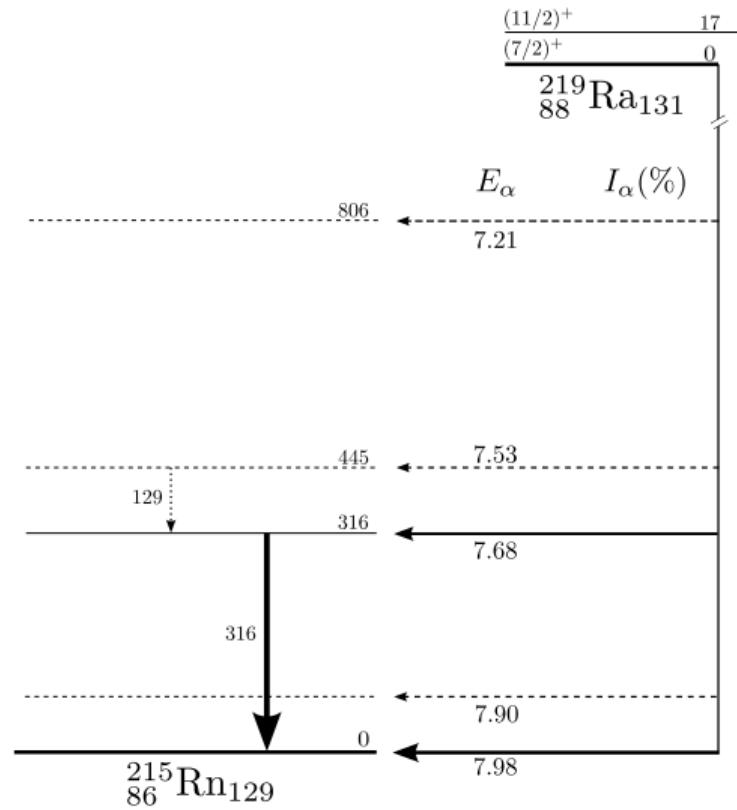
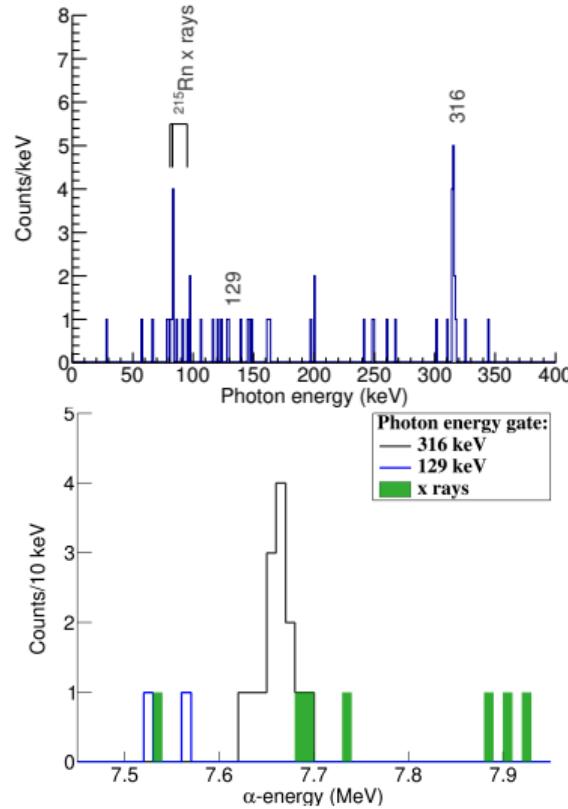
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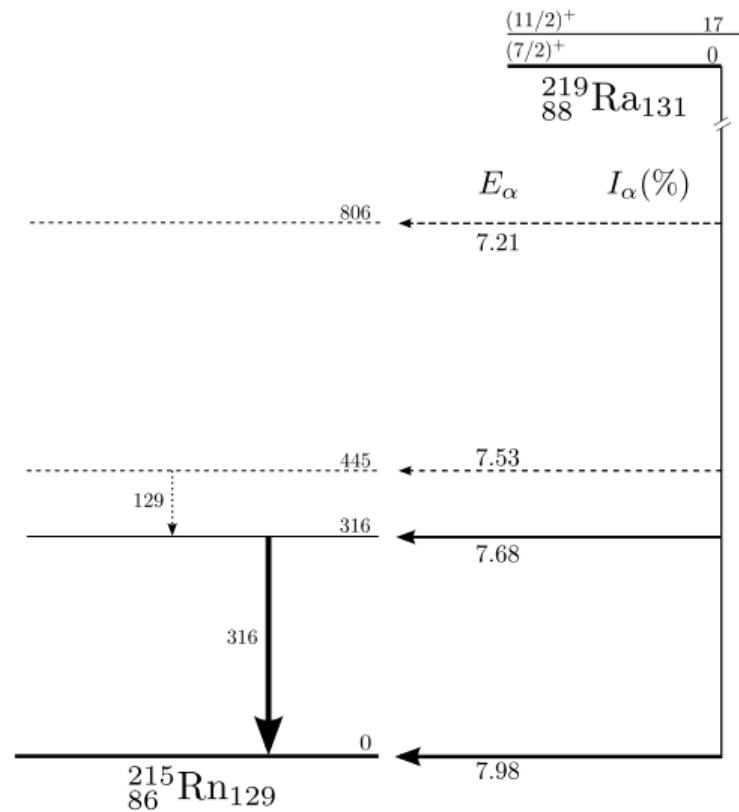
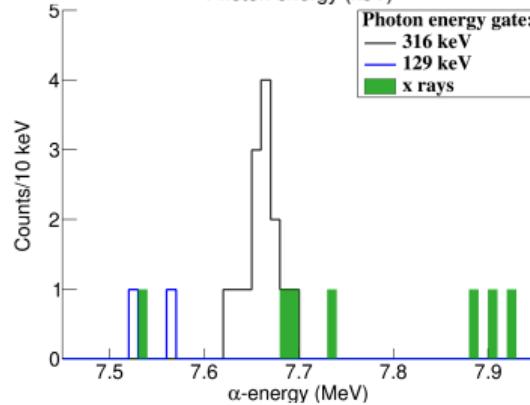
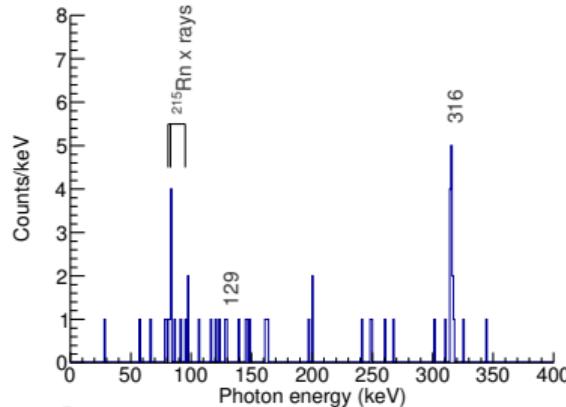
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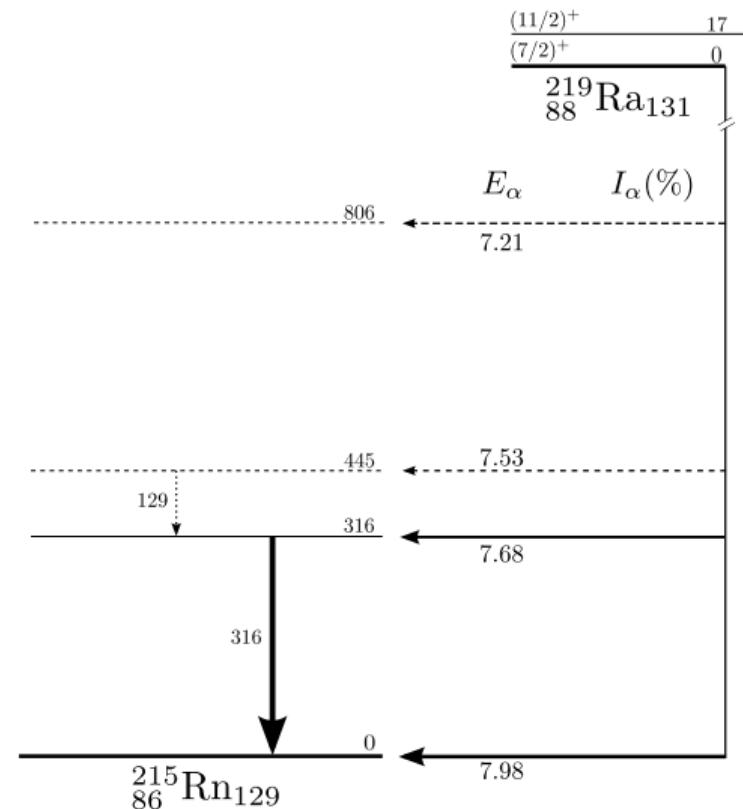
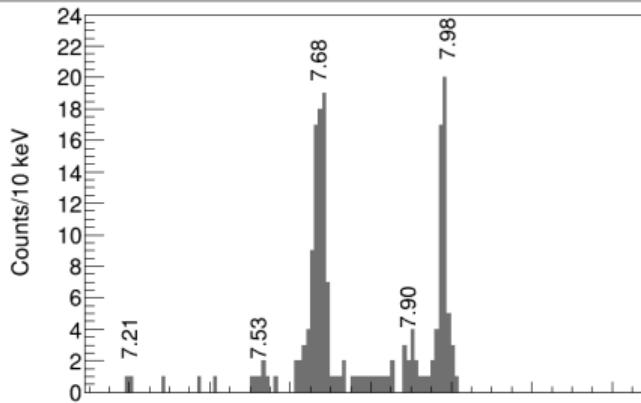
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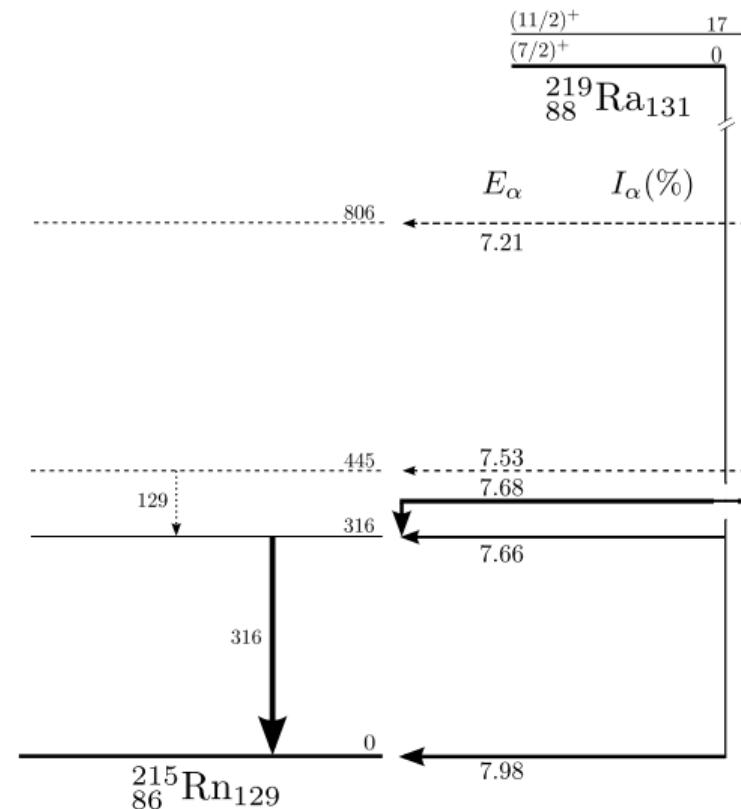
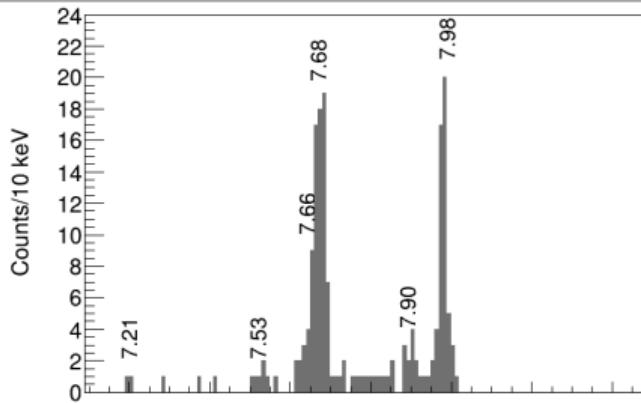
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Decay level scheme $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$



Decay level scheme $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$



Geant4 Simulations of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$

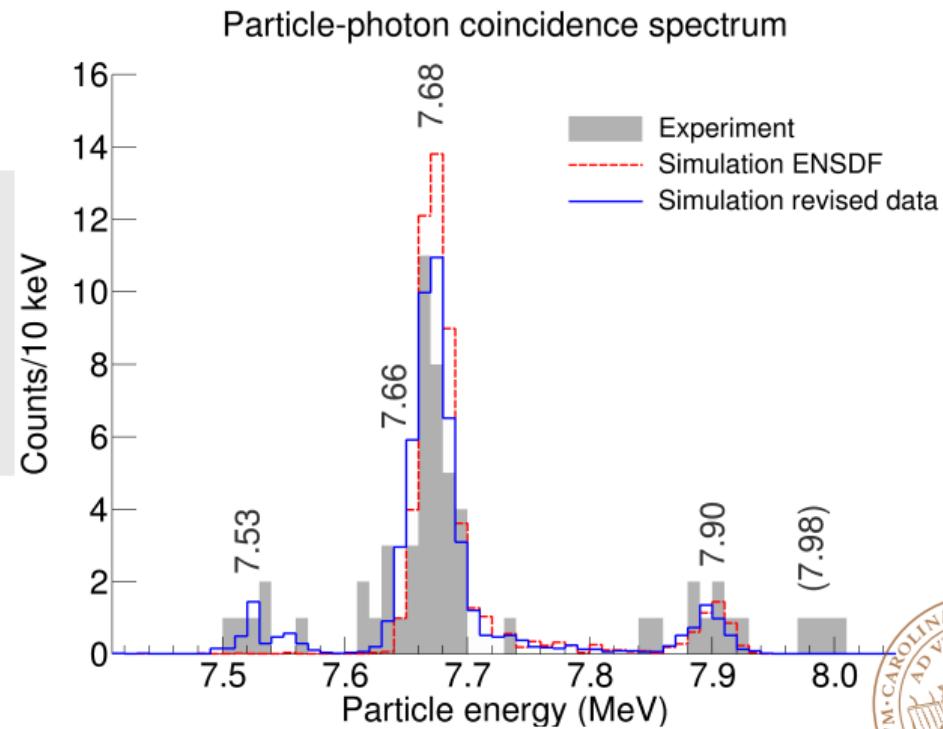
- TASISpec experiment in a virtual Geant4 environment [6].
- 10 000 ^{219}Ra were implanted 80 ± 5 MeV.
- Particle and photon spectra were normalised with a common factor.
- Decay scheme complexity built up step-by-step.
- σL of transitions w.r.t. yields in particle and photon spectra were optimised.

[6] L.G. Sarmiento, L.-L. Andersson, and D. Rudolph, Nucl. Instrum. Meth. A **667**, 26–31 (2012).



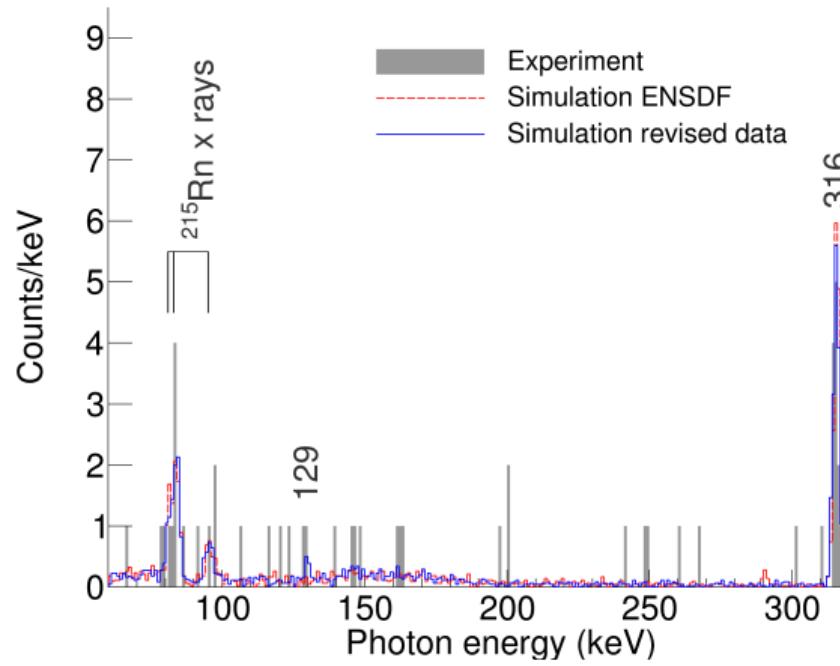
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- Two branches with $E_\alpha = 7.66$ & 7.68 MeV were included.
- Branching ratios were varied for best match.

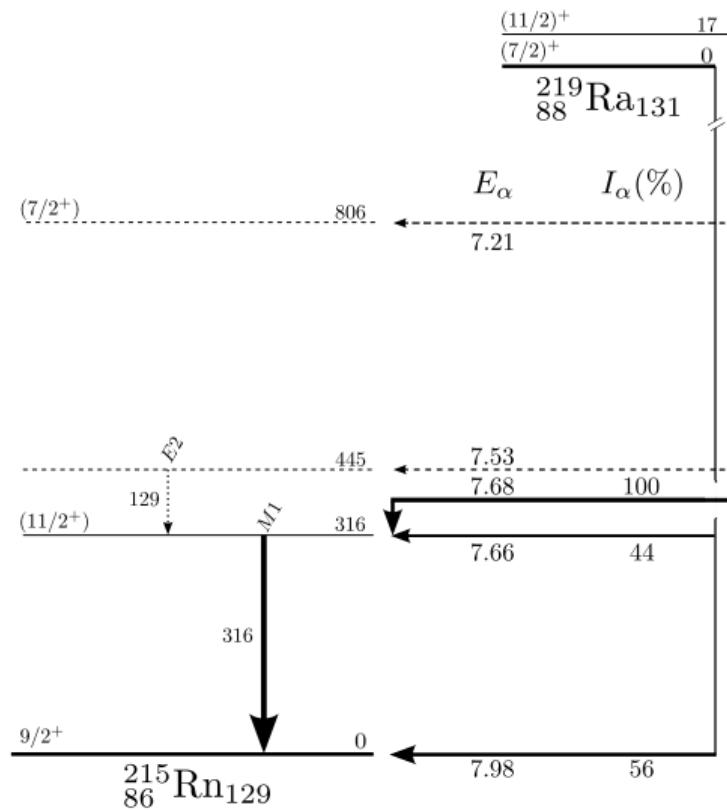


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Photon coincidence spectrum

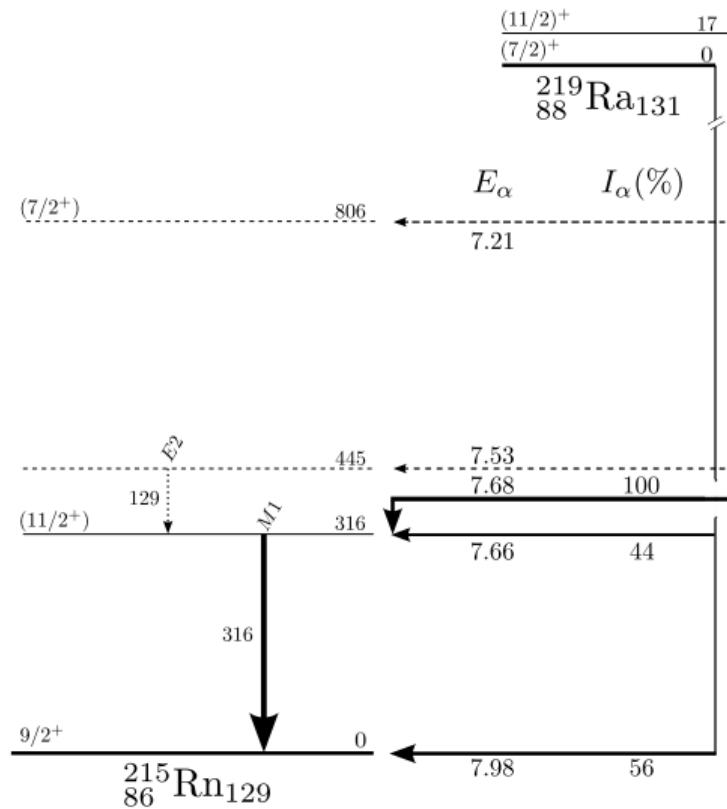


Geant4 Simulations of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$



Geant4 Simulations of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$

What is the origin of the
7.98 MeV branch?



Summary of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$

α decay of ^{219}Ra

^{219}Ra		^{215}Rn	
E_α (MeV)	$t_{1/2}$ (ms)	Q_α (MeV)	E_f (keV)
7.68(2) ^a	10(3)	8.14(2) ^a	316
7.66(2) ^a	10(3)	8.13(2) ^a	316
7.98(1)	8(3)	8.13(2)	0
7.53(2)		8.10(2)	445
7.21(2)		8.15(2)	806

^a Guided by the simulation.



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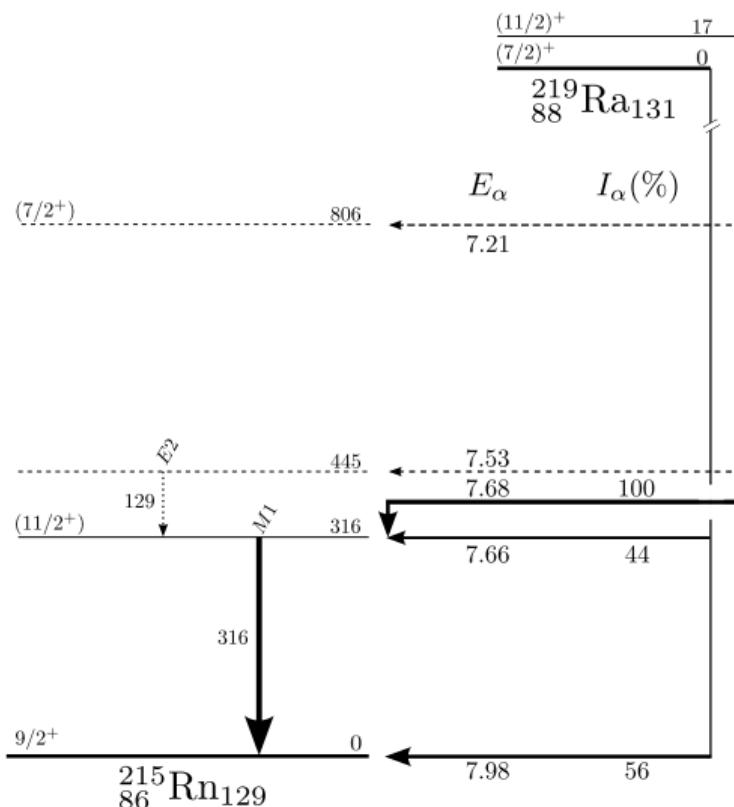
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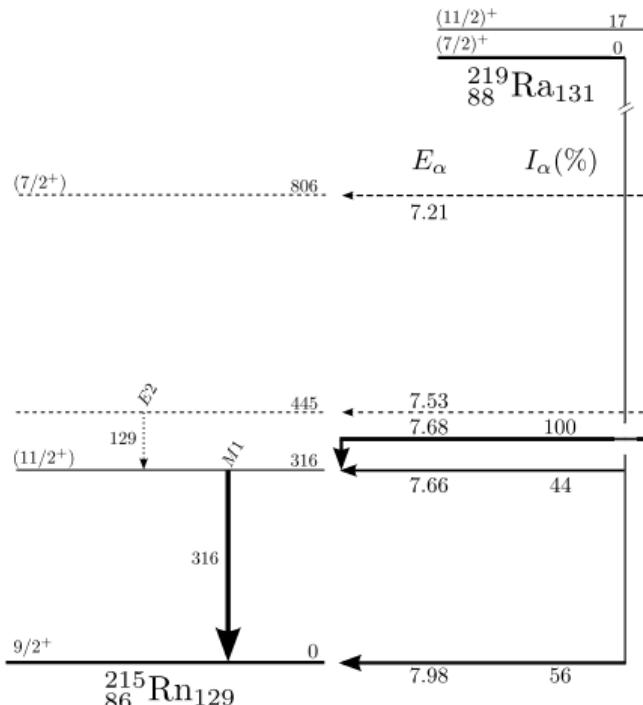


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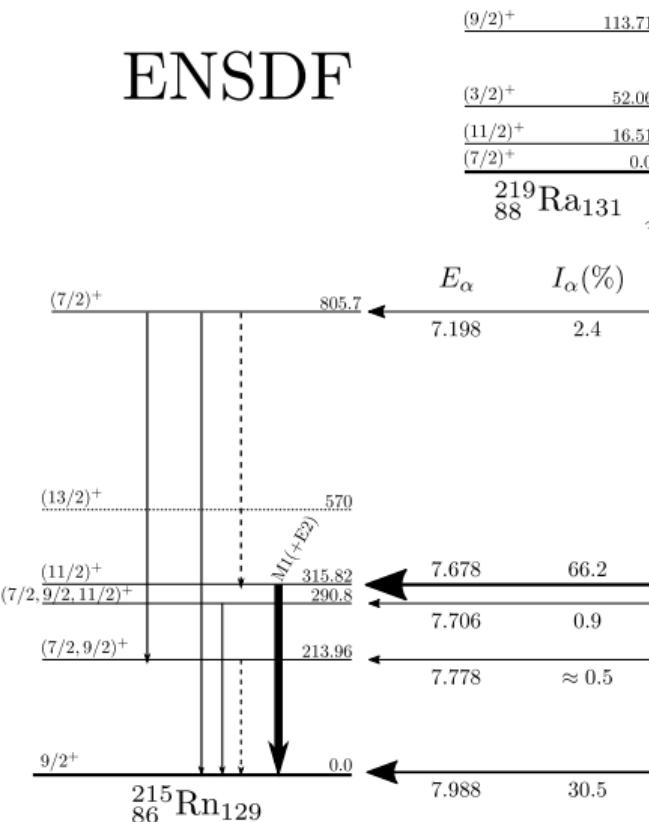


Summary of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$

Present Work



ENSDF



Further decay chains - starting with $^{220,221}\text{Ra}$ and ^{219}Fr

Nucleus	<i>Correlation</i>	<i>Present Work</i>	<i>ENSDF</i>
		E_α (MeV)	
^{215}Rn	$\alpha_1\text{-}\alpha_2^a\text{-}(\alpha_3)$	8.67(1)	8.674(8)
^{220}Ra	(imp ^b) $\text{-}\alpha_1^a\text{-}\alpha_2\text{-}\alpha_3$	7.46(1)	7.453(7)
^{216}Rn	$\alpha_1\text{-}\alpha_2^a\text{-}\alpha_3$	8.05(2)	8.050(10)
^{212}Po	$\alpha_1\text{-}\alpha_2\text{-}\alpha_3^a$	8.78(2)	8.78486(12)
^{219}Fr	(imp ^b) $\text{-}\alpha_1^a\text{-}\alpha_2\text{-}\alpha_3$	7.32(1)	7.3123(18)
^{215}At	$\alpha_1\text{-}\alpha_2^a\text{-}\alpha_3$	8.02(1)	8.026(4)
^{221}Ra	(imp ^b) $\text{-}\alpha_1^a\text{-}\alpha_2\text{-}\alpha_3$	6.76(1)	6.754(5)
^{217}Rn	$\alpha_1\text{-}\alpha_2^a\text{-}\alpha_3$	7.74(1)	7.741(2)
^{213}Po	$\alpha_1\text{-}\alpha_2\text{-}\alpha_3^a$	8.37(1)	8.376(3)

^aStep corresponding to the isotope that is focused.



Further decay chains - starting with $^{220,221}\text{Ra}$ and ^{219}Fr

Nucleus	Correlation	Present Work	ENSDF
		$t_{1/2}$	
^{215}Rn	$\alpha_1-\alpha_2^a-(\alpha_3)$	2.5(3) μs	2.30(10) μs
^{220}Ra	(imp ^b)- $\alpha_1^a-\alpha_2-\alpha_3$	19(3) ms	18(2) ms
^{216}Rn	$\alpha_1-\alpha_2^a-\alpha_3$	29(4) μs	45(5) μs
^{212}Po	$\alpha_1-\alpha_2-\alpha_3^a$	0.35(6) μs	0.299(2) μs
^{219}Fr	(imp ^b)- $\alpha_1^a-\alpha_2-\alpha_3$	28(3) ms	20(2) ms
^{215}At	$\alpha_1-\alpha_2^a-\alpha_3$	37(3) μs	0.10(2) ms
^{221}Ra	(imp ^b)- $\alpha_1^a-\alpha_2-\alpha_3$	16(2) s	28(2) s
^{217}Rn	$\alpha_1-\alpha_2^a-\alpha_3$	0.67(6) ms	0.54(5) ms
^{213}Po	$\alpha_1-\alpha_2-\alpha_3^a$	3.5(3) μs	3.72(2) μs

^aStep corresponding to the isotope that is focused.

^bStep in the correlation search that was merely used to estimate the half-life.



Further decay chains - starting with $^{220,221}\text{Ra}$ and ^{219}Fr

Measured half-lives differ significantly in the cases of:

- ^{216}Rn [1].
- ^{219}Fr & ^{215}At [7,8].
- ^{221}Ra [9].
- ^{217}Rn [10].

- [1] K. Valli, *et al.*, Phys. Rev. C, **1**, 6 (1970).
[7] G. Bastin *et al.*, J. Phys.(Paris) Suppl.No.1, Colloq.C1-181 (1968).
[8] G. Graeffe and P. Kauranen, J. Inorg. Nucl. Chem., **28** 933–936 (1966).
[9] P. A. Tove, Arkiv Fysik, **13** (1958).
[10] C. P. Ruiz, United States (1961).



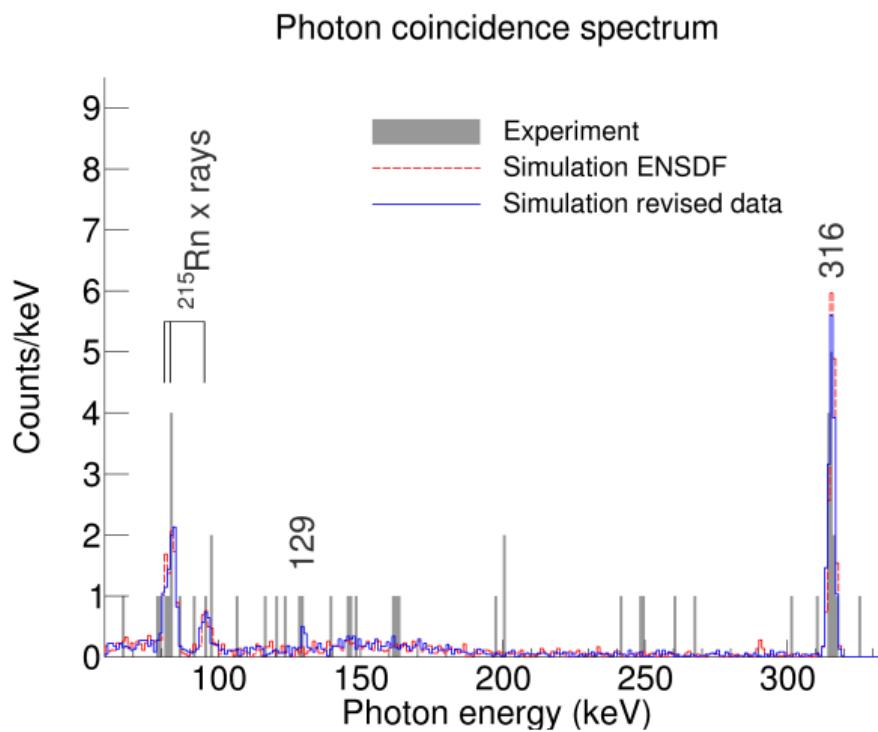
Conclusion

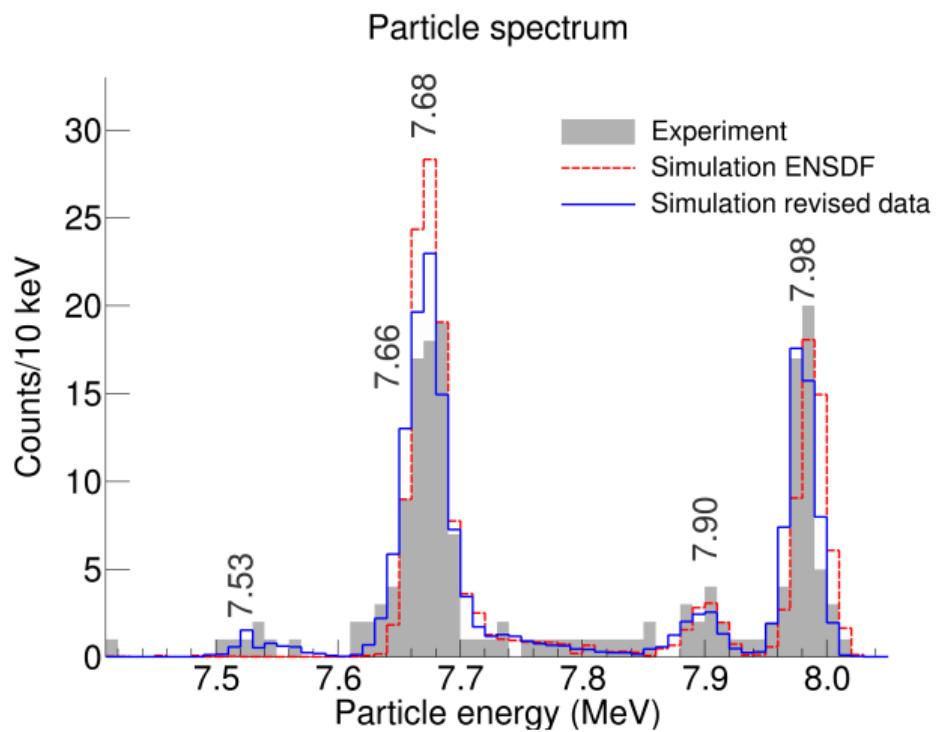
- An α -decay branch from the excited state at 17 keV in ^{219}Ra , unknown in previous decay spectroscopy experiments, is proposed.
- The results are consistent with Geant4 simulations.
- To gain more confidence in the nuclear structure interpretation further experimental studies are encouraged.
- Soon send around to co-authors.

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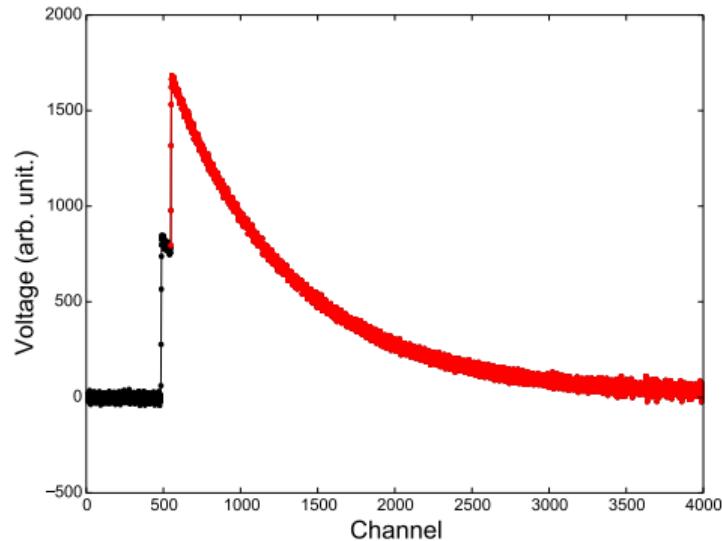
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Geant4 Simulations of $^{219}\text{Ra} \rightarrow ^{215}\text{Rn}$ 

Fast Sampling ADCs

Pile-ups

Digital



Analogue

