Colloque GANIL 2021

New isomeric states in ^{255}No and ^{256}No with GABRIELA@SHELS

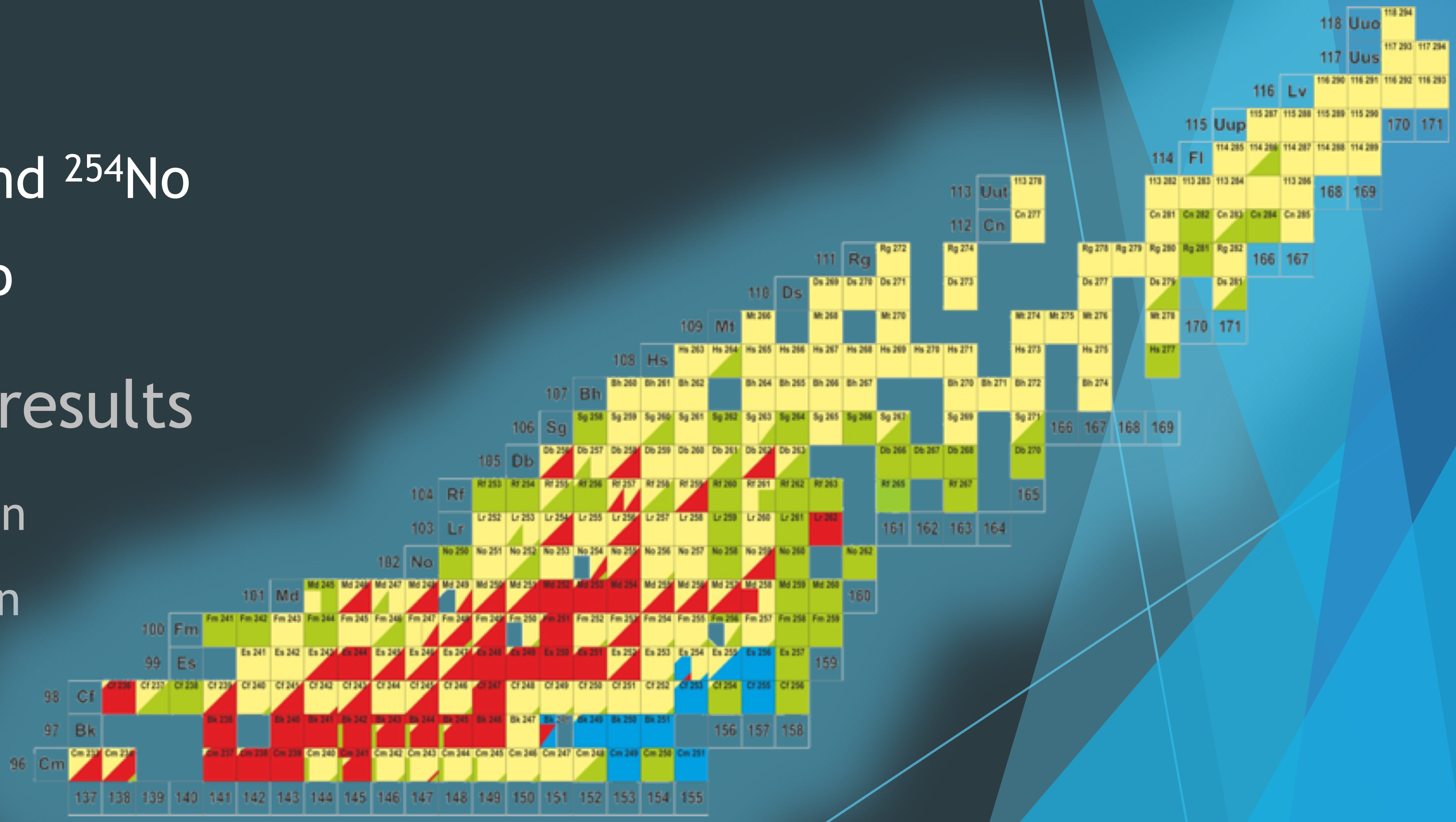
PhD supervisor : Benoit Gall
Kieran Kessaci

I. Context

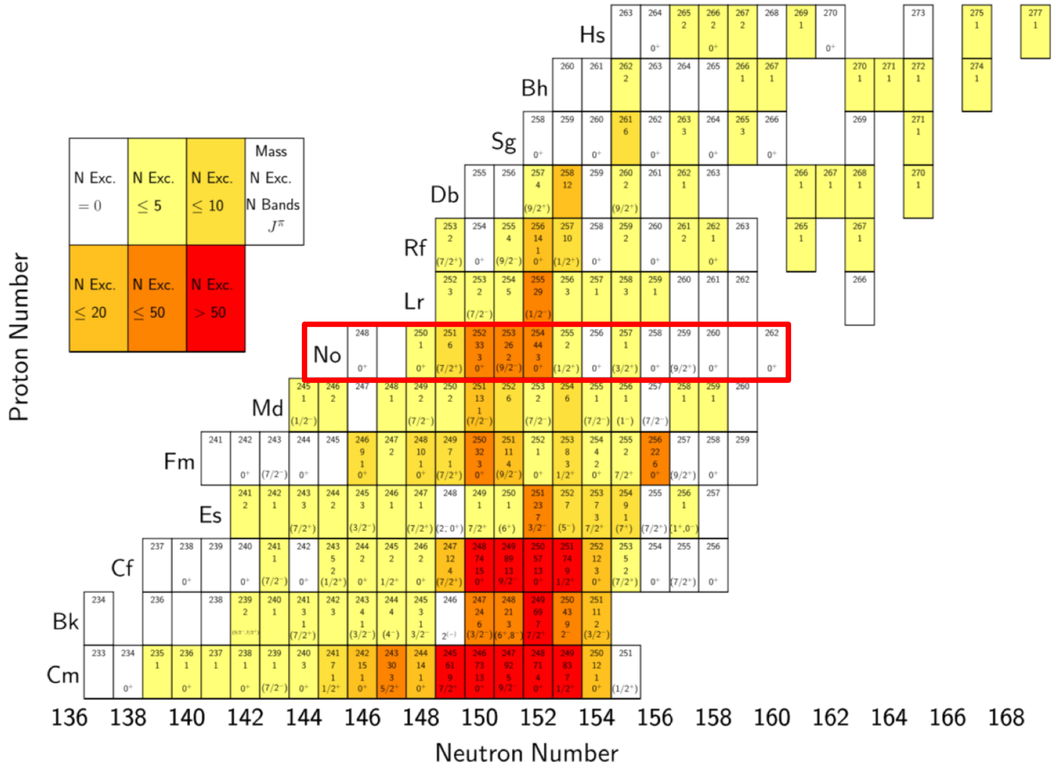
- Spectroscopy around ^{254}No
- Experimental setup

II. Data analysis and results

- $^{22}Ne + ^{238}U \rightarrow ^{256}No + 4n$
- $^{48}Ca + ^{208}Pb \rightarrow ^{255}No + n$



Spectroscopy Around ^{254}No



Ch. Theisen et al. / Nuclear Physics A 944 (2015) 333–375

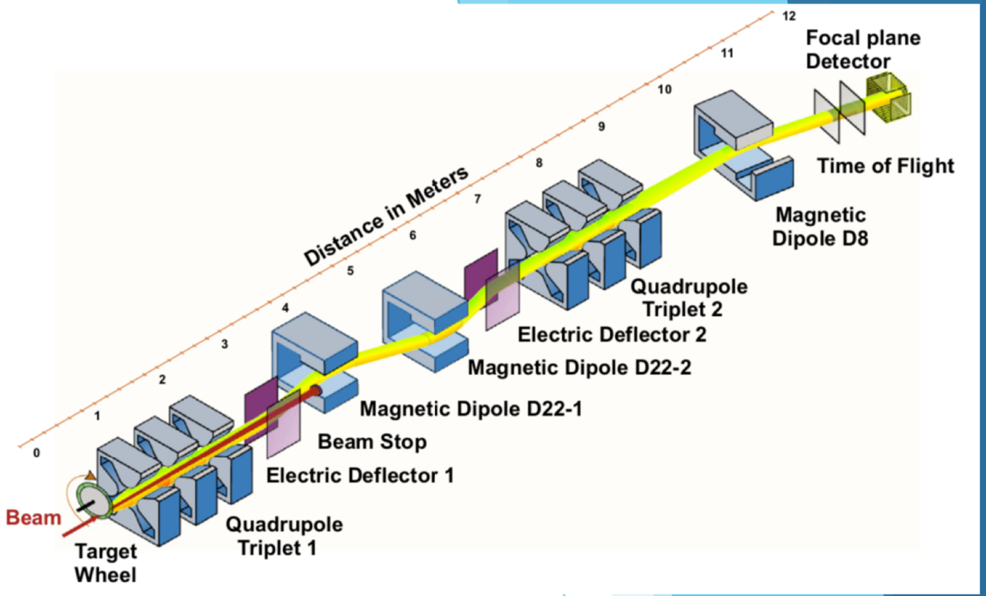
- Chart of known excited states in the heavy and superheavy region
- The region around $^{254}_{102}No$ was widely studied by cold fusion
- Many rotational structures and high-K isomers were observed
- Informations on neutron rich isotopes are scarce
- ^{256}No in hot fusion : $^{22}_{10}Ne + ^{238}_{92}U \longrightarrow ^{256}_{102}No + 4n$
- ^{255}No in cold fusion : $^{48}_{20}Ca + ^{208}_{82}Pb \rightarrow ^{255}_{102}No + n$

Setup

SHELS : Separator for Heavy Elements Spectroscopy

Reaction	ERs transmission	
	Old	New
$^{22}Ne(^{198}Pt,5\text{-}7n)^{213-215}Ra$	0.03	0.040 ± 0.015
$^{22}Ne(^{197}Au,4\text{-}6n)^{213-215}Ac$	0.03	0.065 ± 0.030

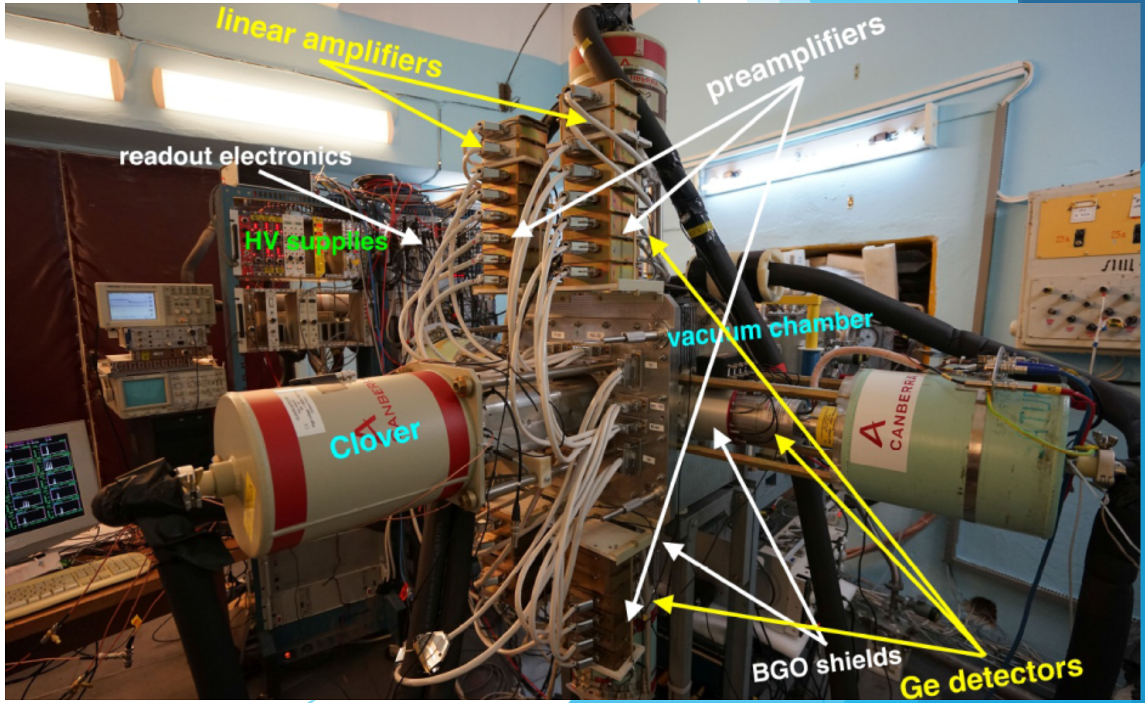
A. G. Popeko et al, Nuclear Instruments and Methods in Physics Research B 376 (2016) 140–143



- $^{22}_{10}Ne + ^{238}_{92}U \longrightarrow ^{260-x}_{102}No + xn$
  → First asymmetric experiment with this setup

GABRIELA : Gamma Alpha Beta Recoil Investigations with the ELectromagnetic Analyzer

- DSSD + Tunnels + 4 Ge Monocrystals + 1 CLOVER
- One of the ToF foils was unmounted because of the slowness of the recoils
  → High DSSD threshold (150-200 keV)



A. Yeremin, O. Malyshev and al. - EPJ Web of Conferences 86, 00065 (2015)

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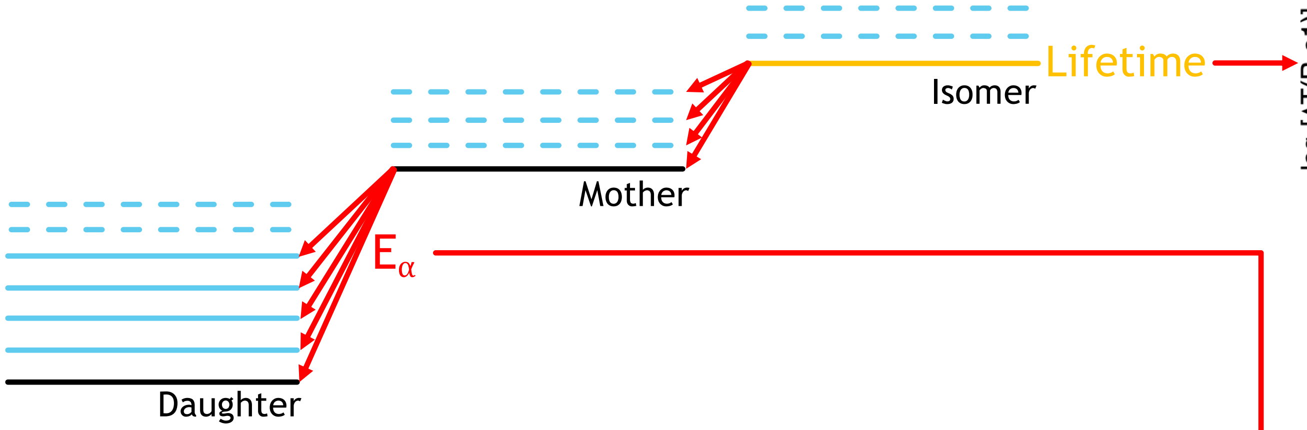
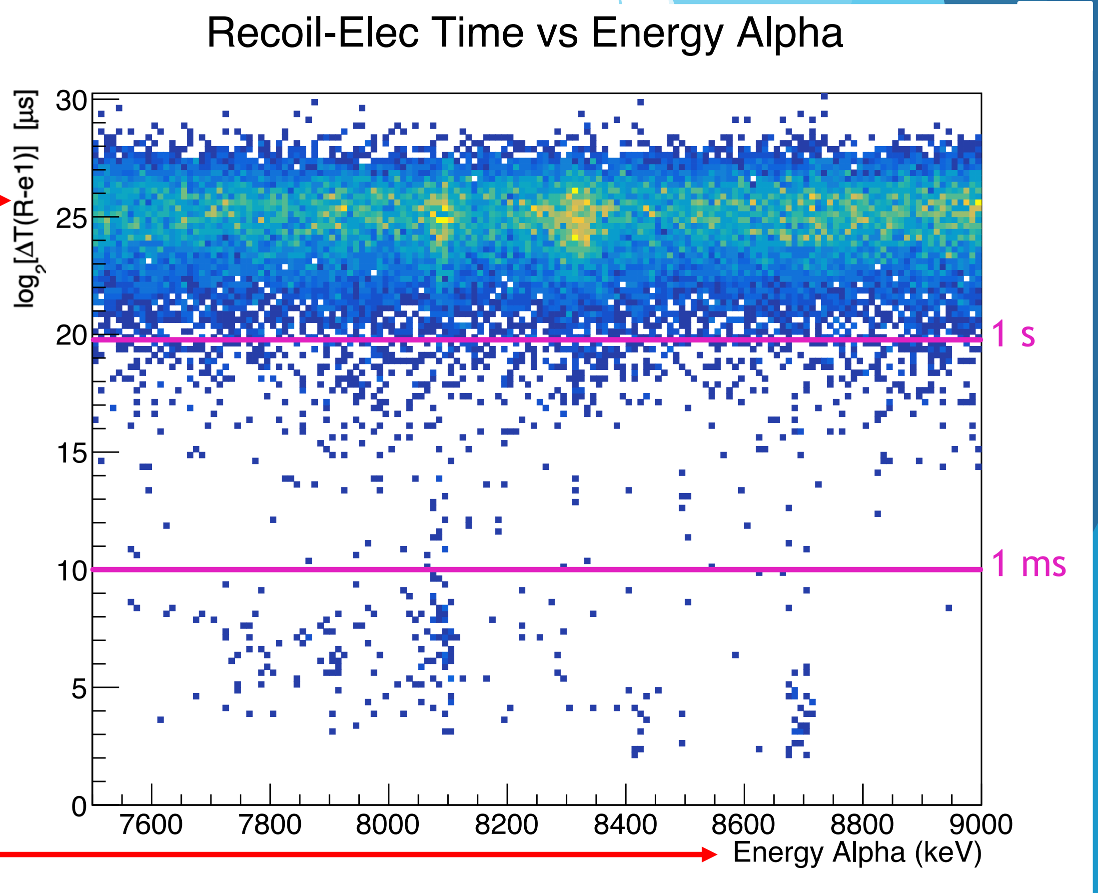
$^{22}\mathrm{Ne} + {}^{238}\mathrm{U} \rightarrow {}^{256}\mathrm{No} + 4n$

- This plot shows the lifetime of isomers as a function of the subsequent alpha decay energy





- ^{256}No Alpha decay energy 8430 keV (M. Asai et al.)
- 8430 keV : 15 events of a new isomer in ^{256}No
- Between 7700 and 8150 keV : isomeric decays in ^{255}No

M. Asai et al., JAEA-Review 2016-025 (2016) pp. 9-10.

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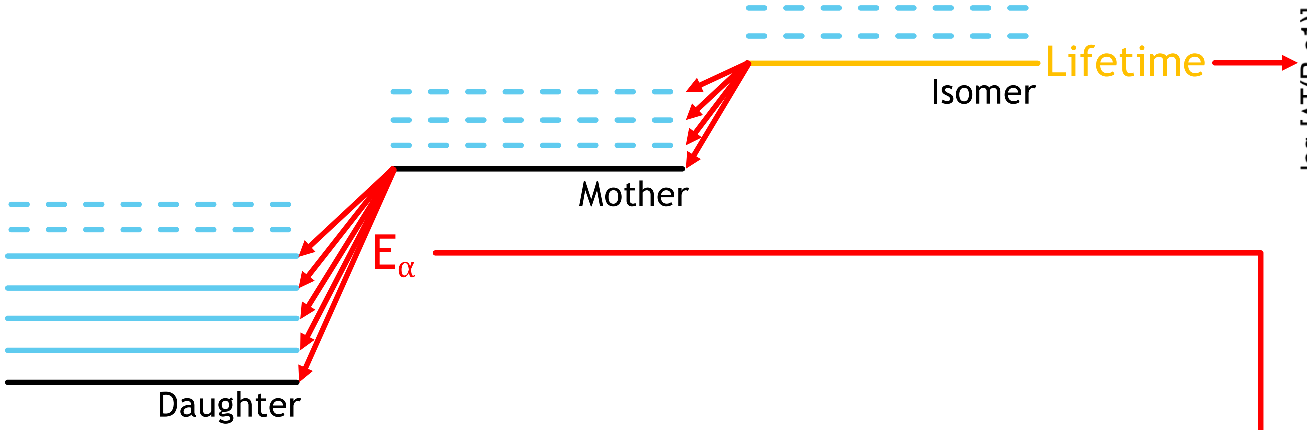

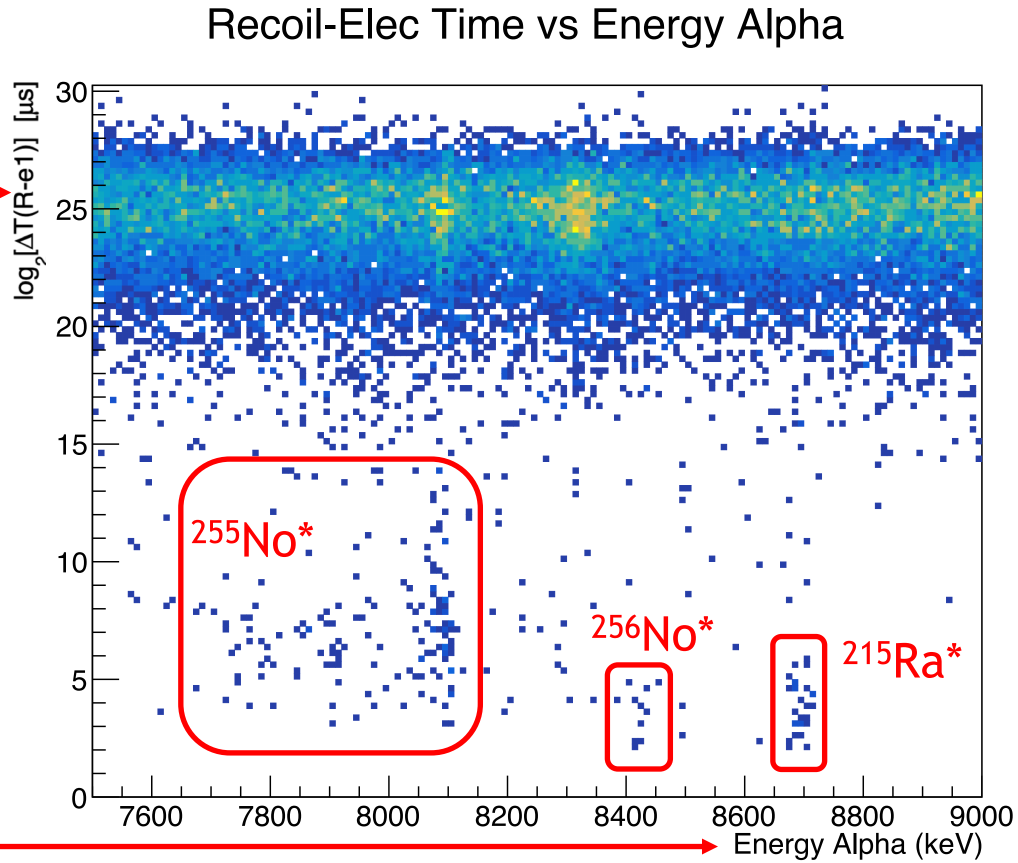

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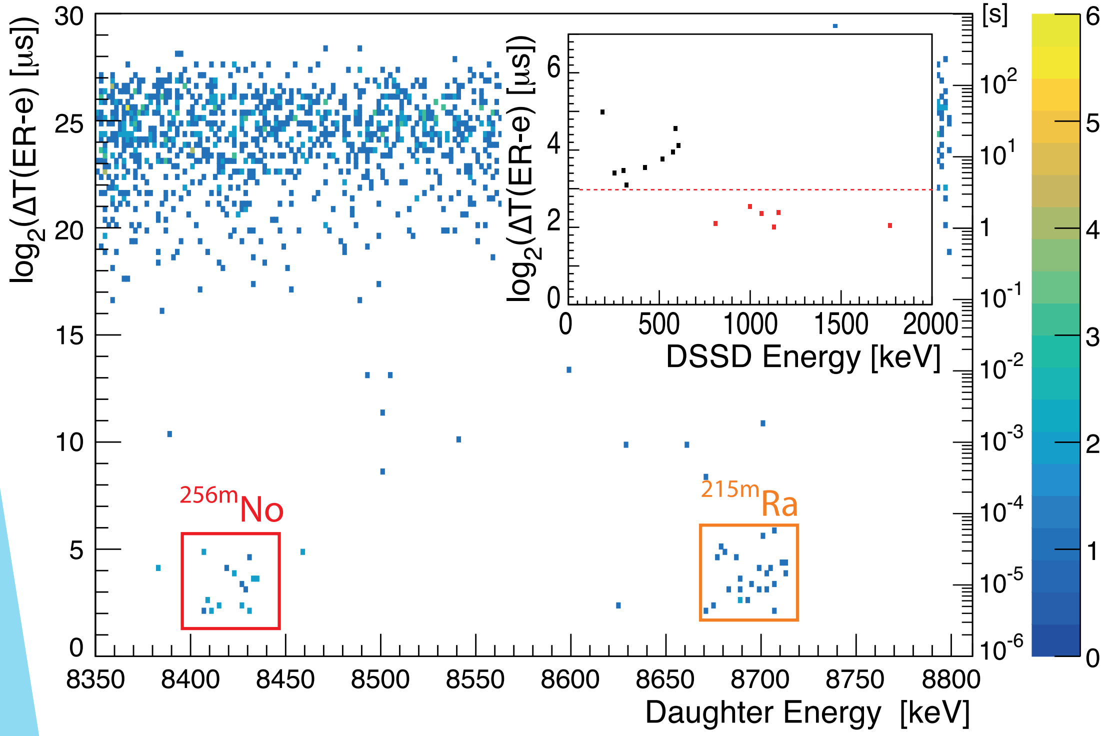
^{256}No Isomeric state(s)



1 σ → Confidence level 68.27%

$T_{1/2} = 7{,}8^{+2{,}7}_{-1{,}6}$ µs

- 15 events over one month of beam-time (identified by the calorimetric method of G.D.Jones)
- 738 ^{256}No implanted in the focal plane
  → Isomeric ratio 15/738 ≃ 4%
- 9 events without pile-up
- K and L X-rays of Nobelium observed
  → Conversion electrons
- γ rays considered with and without add-back mode for the CLOVER detector

→ E*>1089keV

DSSD energy (keV)	Tunnel energy (keV)	γ-ray energy (keV)	Sum (keV)
187	-	-	187
254	101	27	382
421	63	-	484
518	121	-	639
318	211	463^{AB}	992
576	91	127 // 205	999
589	189	255	1033
604	462	23	1089
809^{PU}	86	133	-
999^{PU}	139	127	-
1063^{PU}	227	372^{AB}	-
1131^{PU}	-	307	-
1154^{PU}	28	382	-
1768^{PU}	-	0	-

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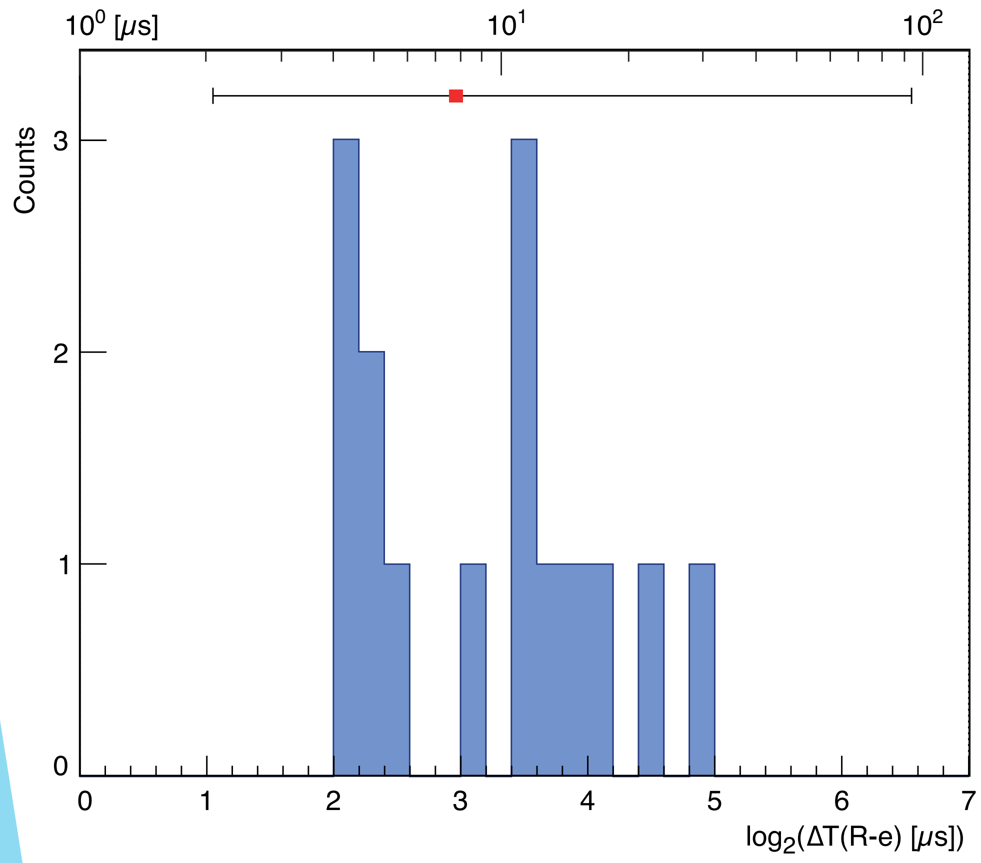

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^{256}No Isomeric state(s)

Inputs :

- $T_{1/2}$ = 7,8 $^{+8,3}_{-2,7}$ µs
- Isomeric ratio ≃ 4%
- Excitation energy > 1089keV
- Electron shower up to ≃ 600keV in the decay

High-K, $t_{1/2}$= $7.8^{+9.0}_{-2.7}$ μs isomeric state in $^{256}_{102}$No$_{154}$

K. Kessaci[a,*], B.JP. Gall[a], O. Dorvaux[a], A. Lopez-Martens[b], D. Ackermann[d], R. Chakma[b], M.L. Chelnokov[c], V.I. Chepigin[c], M. Forge[a], K. Hauschild[b], A.V. Isaev[c], I.N. Izosimov[c], D.E. Katrasev[c], A.A. Kuznetsova[c], O.N. Malyshev[c], J. Piot[d], A.G. Popeko[c], Yu.A. Popov[c], E.A. Sokol[c], A.I. Svirikhin[c], A.V. Yeremin[c]

[a] *Université de Strasbourg, CNRS, IPHC UMR 7178, 67037 Strasbourg, France*
[b] *IJCLab, IN2P3-CNRS, Université Paris Saclay, 91400 Orsay, France*
[c] *Flerov Laboratory of Nuclear Reactions, JINR, 141 980 Dubna, Russia*
[d] *GANIL, CEA/DSM-CNRS/IN2P3, Caen, France*

Accepted in PRC

Abstract

Isomeric states in ^{256}No were investigated using internal conversion electron and γ-ray spectroscopy with GABRIELA at the focal plane of the the SHELS recoil separator. The nuclei of interest were produced using the hot fusion-evaporation reaction ^{238}U(^{22}Ne, 4n)^{256}No. The emission of internal conversion electrons and γ-rays occurring between a ^{256}No implantation and a subsequent alpha decay event were studied, resulting in the observation an isomer with an half life of $7.8^{+9.0}_{-3.7}$ μs. It is interpreted on the basis of experimental information from internal conversion electron and γ-ray spectra as well as lifetimes and hindrance in the

Solutions for the observed isomer :

- A 4-qp configuration ?
  → Ratio
  → Electron burst energy
  ? …But why no 2-qp?
  …2-qp configuration below threshold ?

- 2 different 2-qp configurations ?
  → Lifetime distribution
  → long unfavored path // to a short
  ? favored below threshold ?
  → Most likely configuration(s) : 2-qp neutron

Require new experiment with :

- ➢ Lower thresholds
- ➢ Digital electronic ?

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Institut Pluridisciplinaire Hubert CURIEN STRASBOURG

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- ^{48}Ca + ^{208}Pb $\longrightarrow$ ^{255}No + n

^{255}No Isomeric states

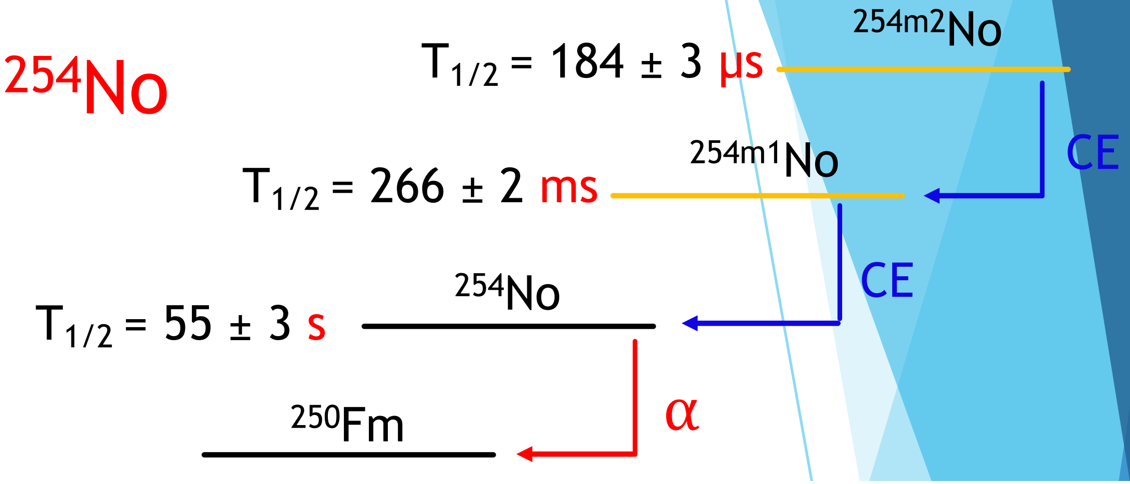
- New results from the cold-fusion experiment

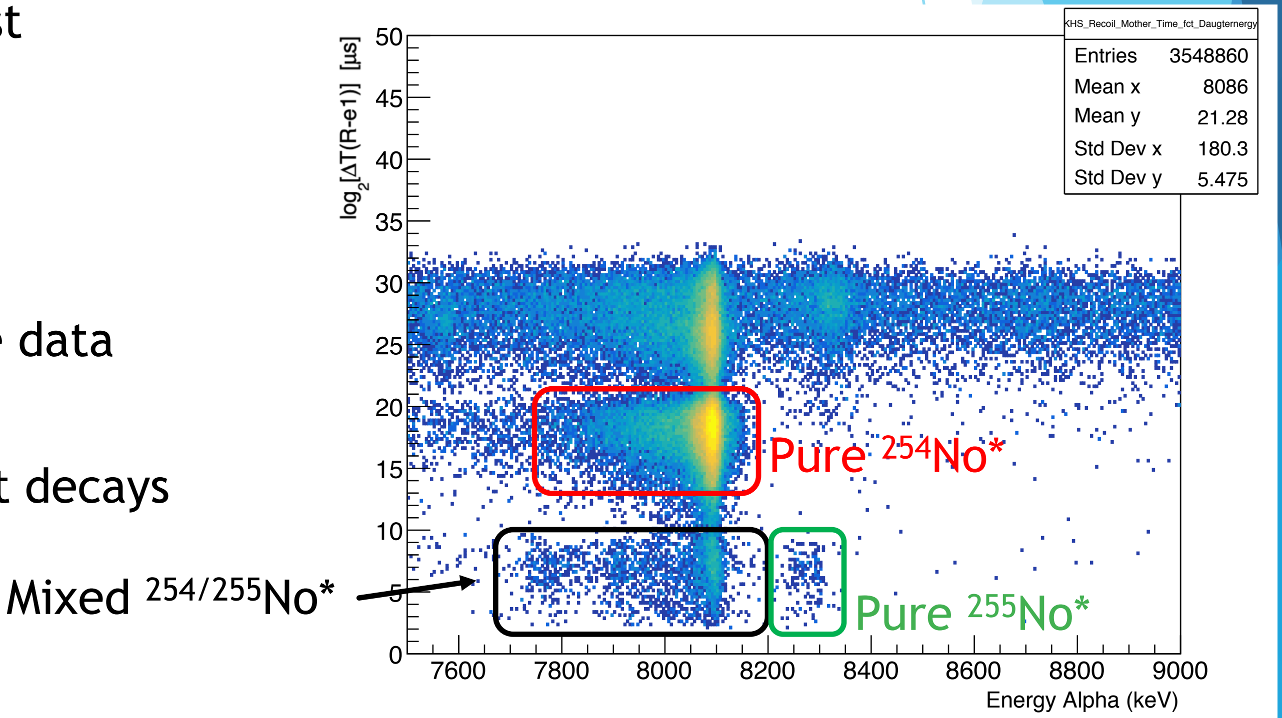
  $^{48}Ca + ^{208}Pb \rightarrow ^{256-x}No + xn$

- First issue :
  - ^{254}No and ^{255}No have common alpha decay energies and common lifetime for the first isomers..
  - How can we distinguish these isomers ?

⟶ Look at the chains up to ^{251}Fm to clean the data
→ Identification

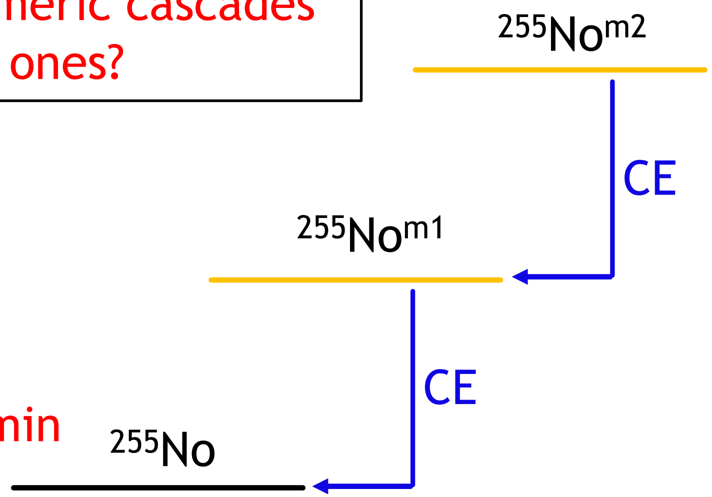
⟶ Then isolate it by correlations between fist decays
→ Study





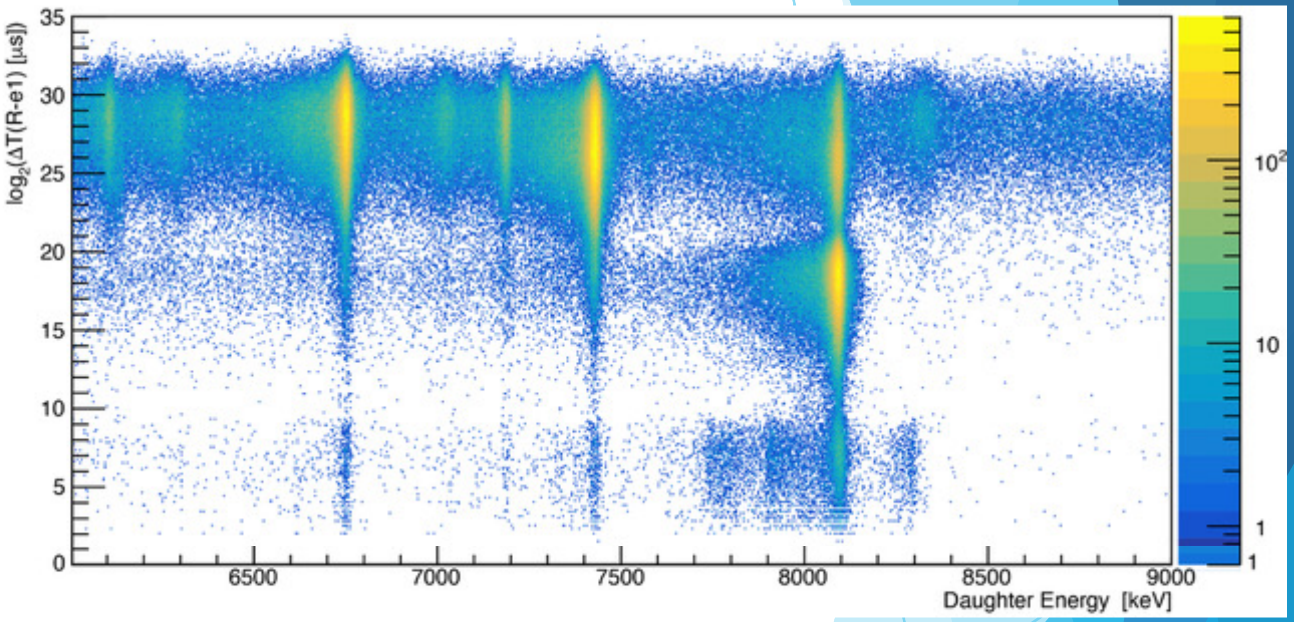
Identification of isomeric states

How to isolate isomeric cascades in ^{255}No from ^{254}No ones?



$T_{1/2} = 3,52 \pm 0,21$ min

$^{48}Ca + ^{208}Pb \rightarrow ^{256-x}No + xn$



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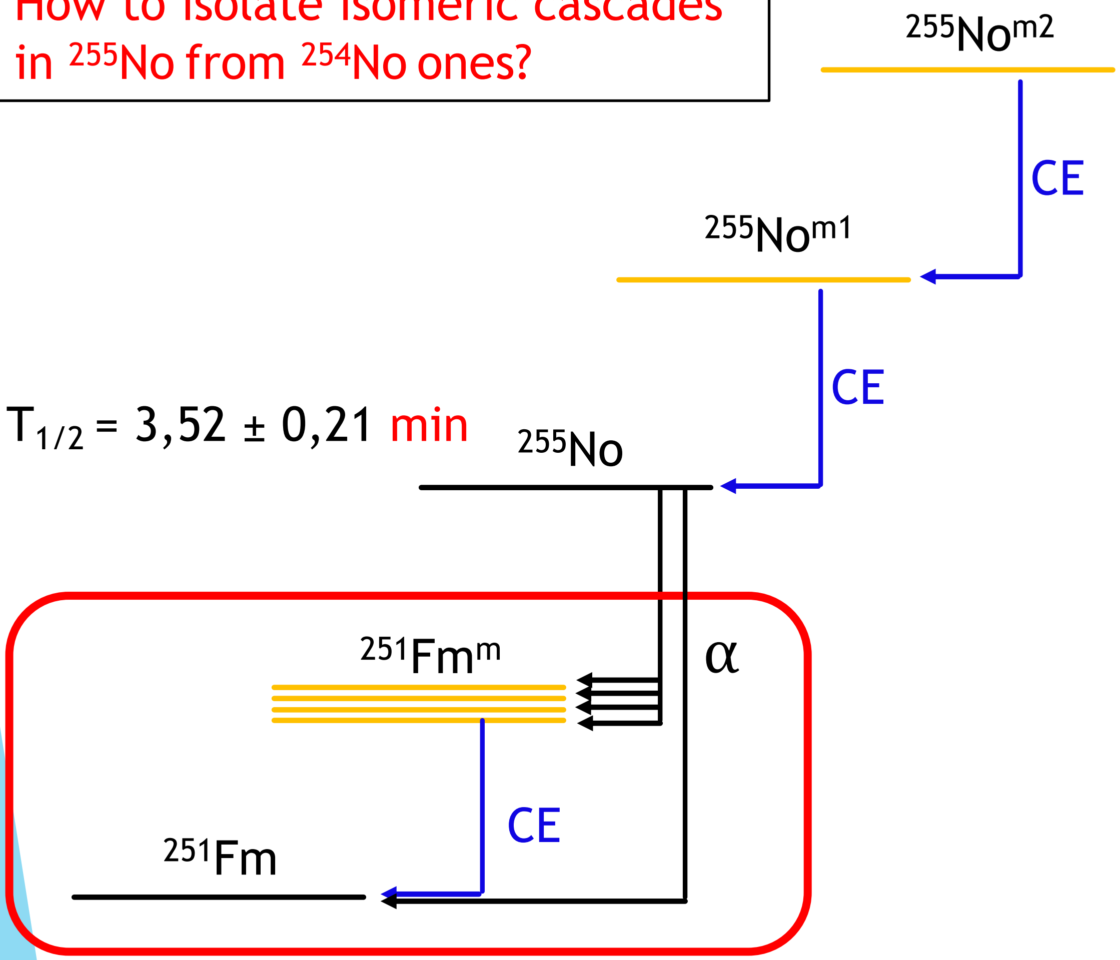

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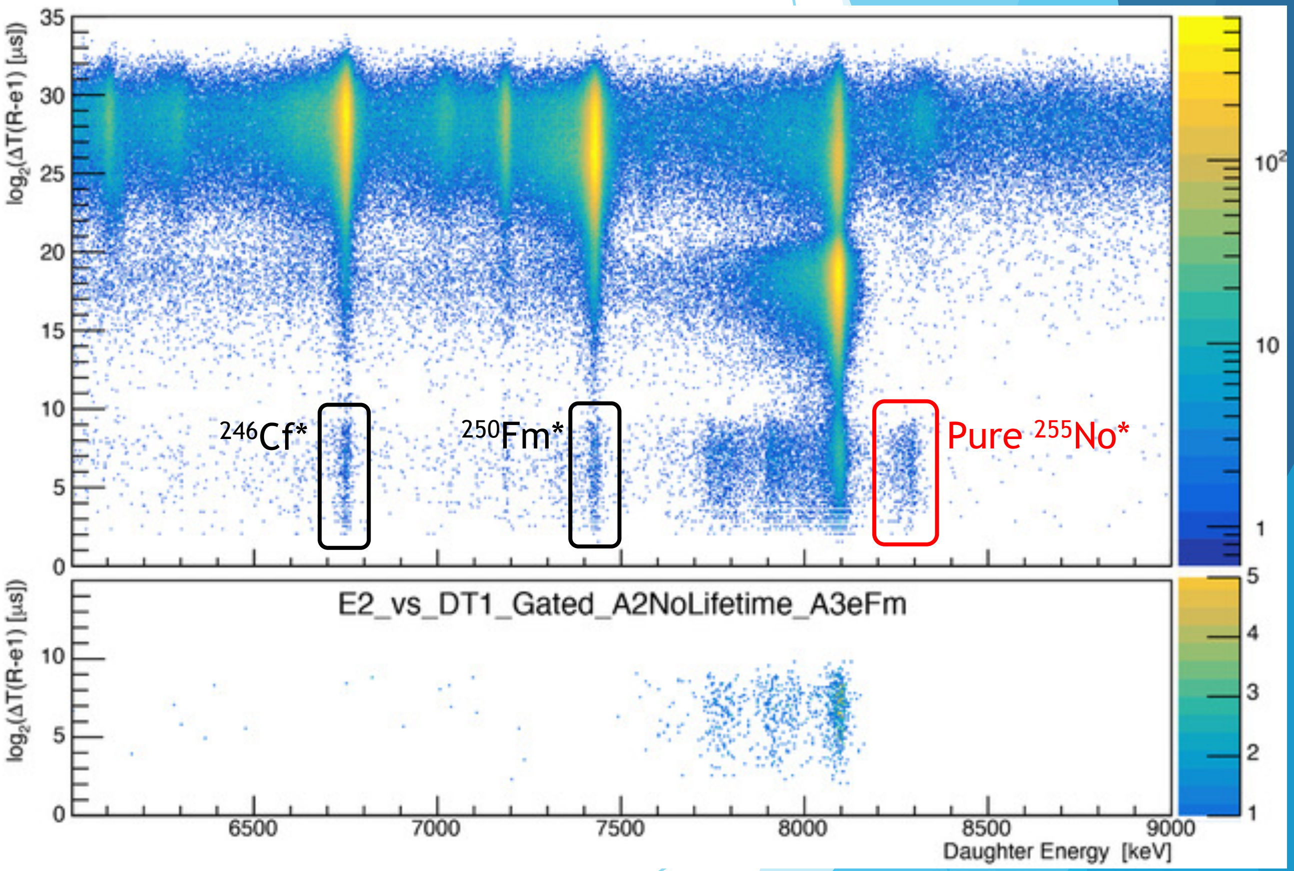

Well known ^{251}Fm → Identification of the decay chain

Identification of isomeric states

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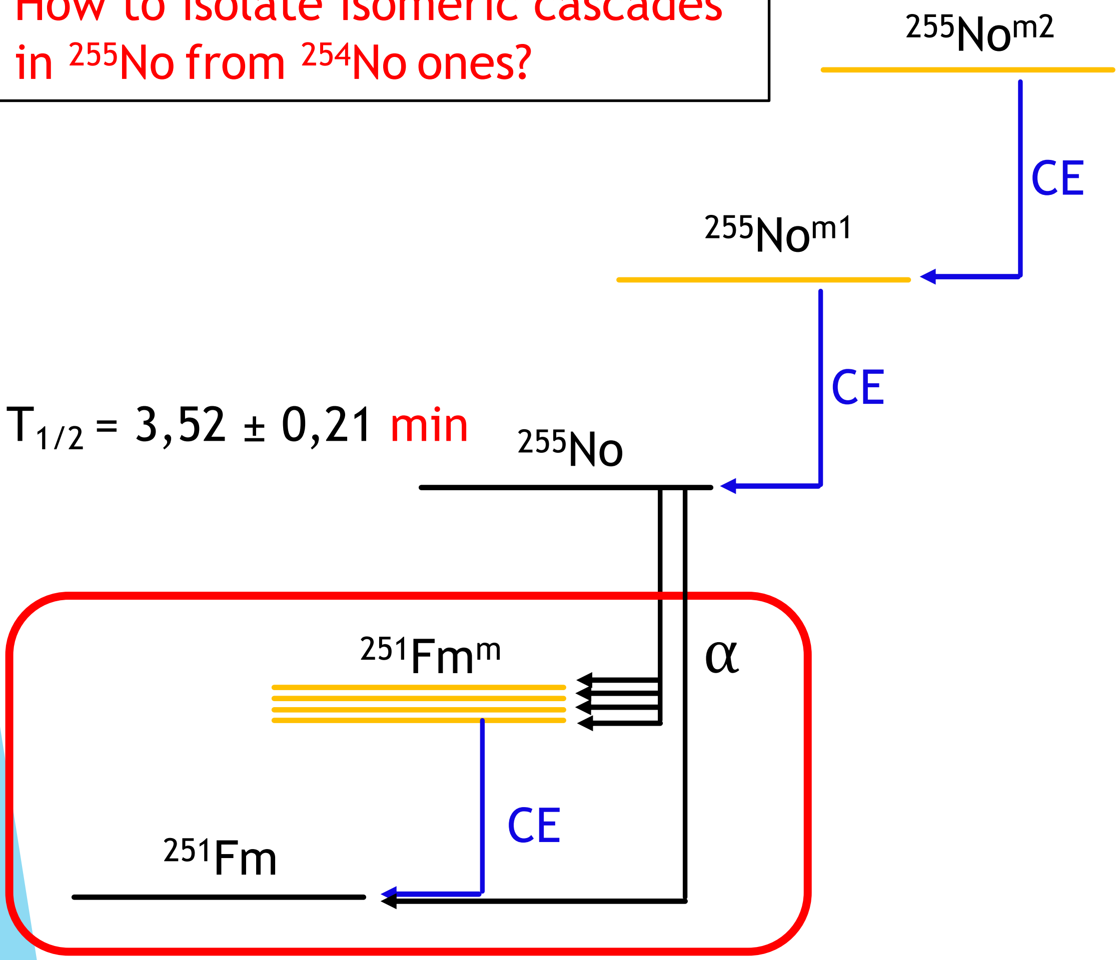

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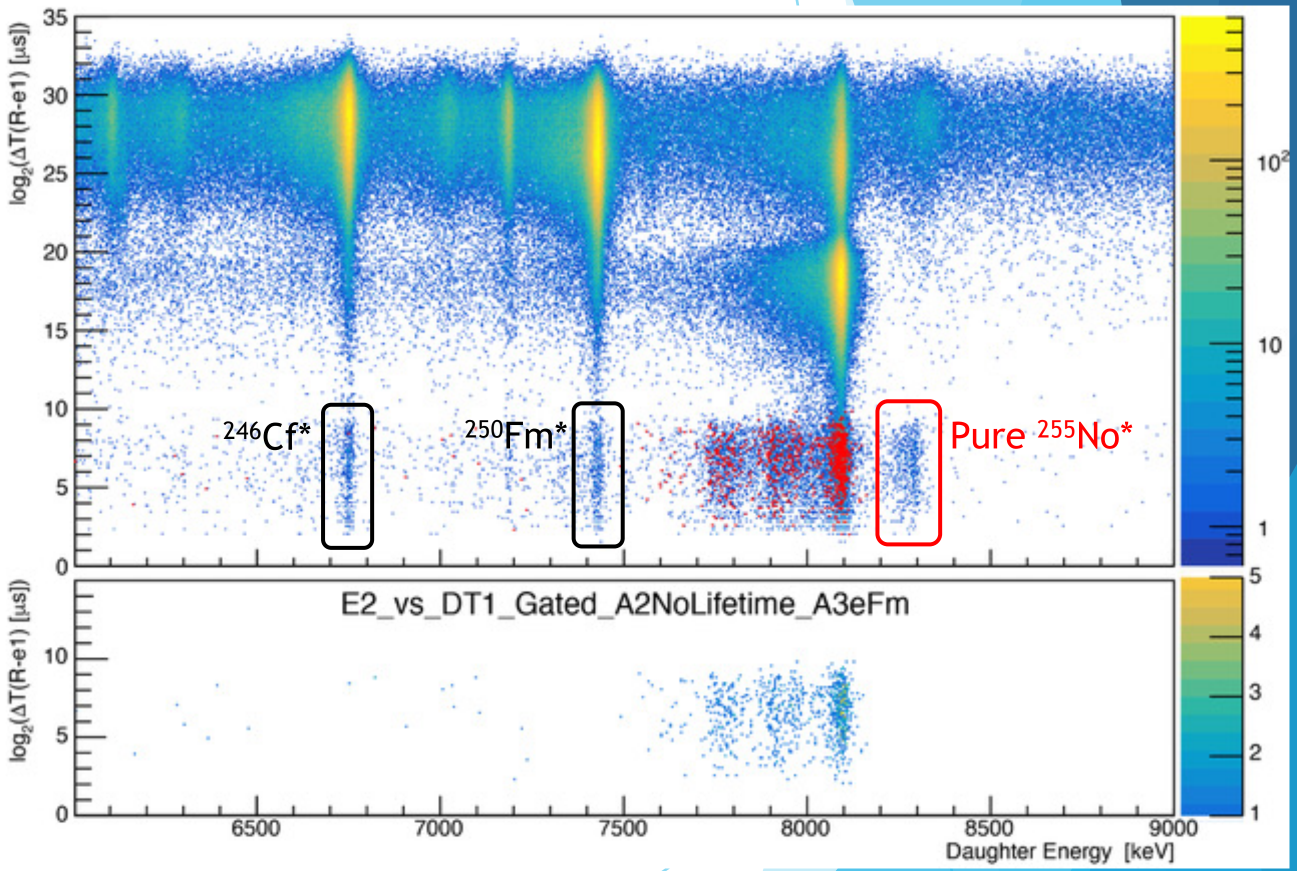
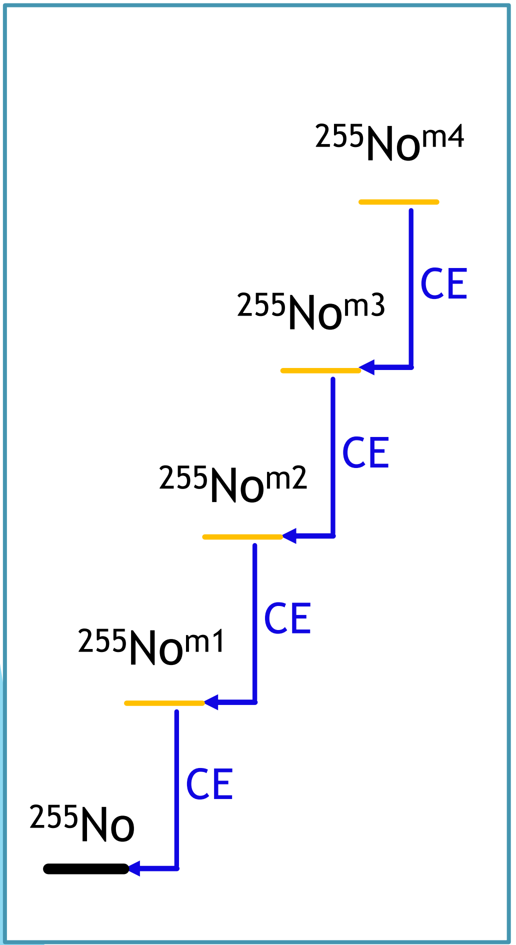
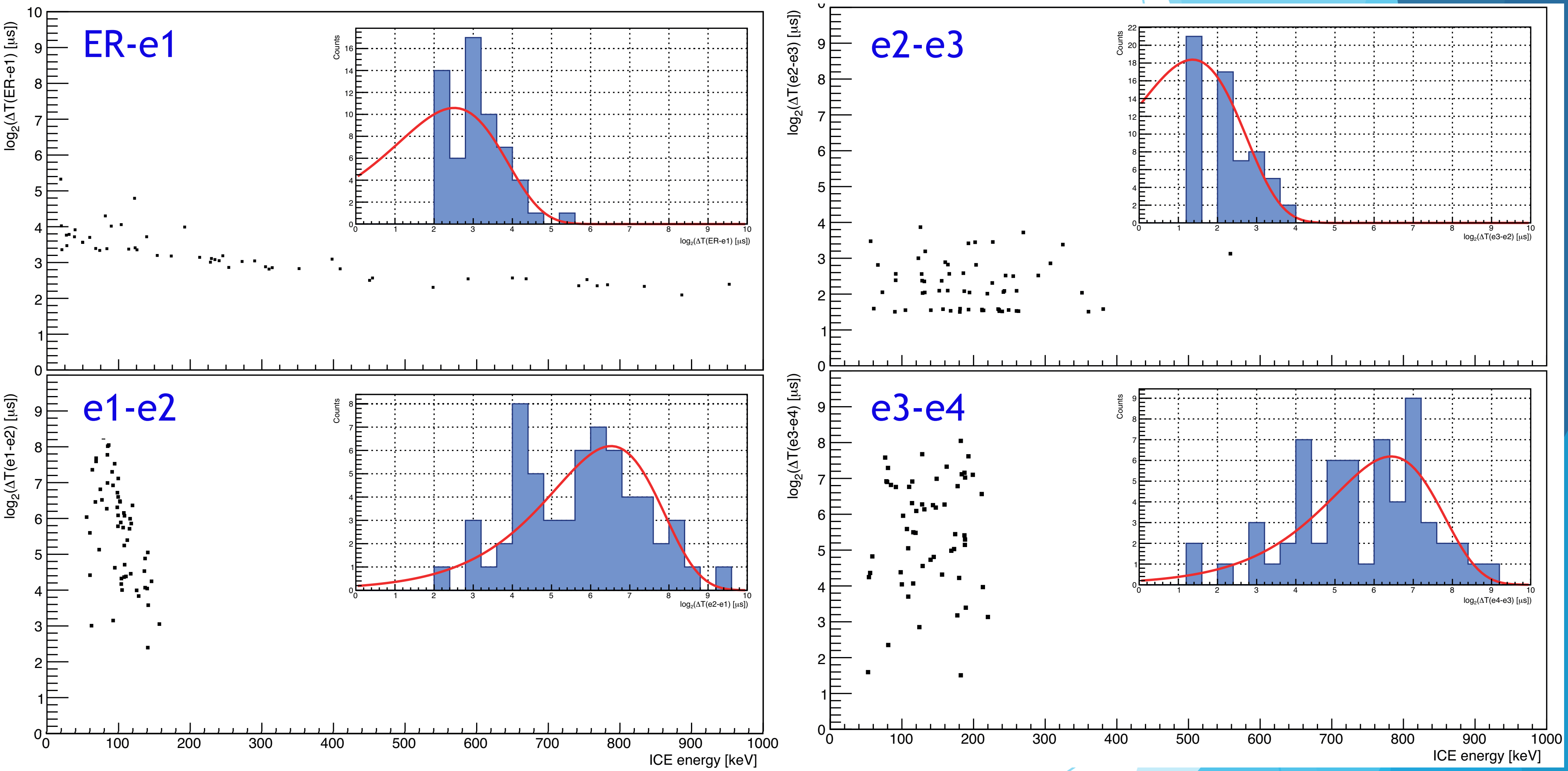


Well known ^{251}Fm → Identification of the decay chain

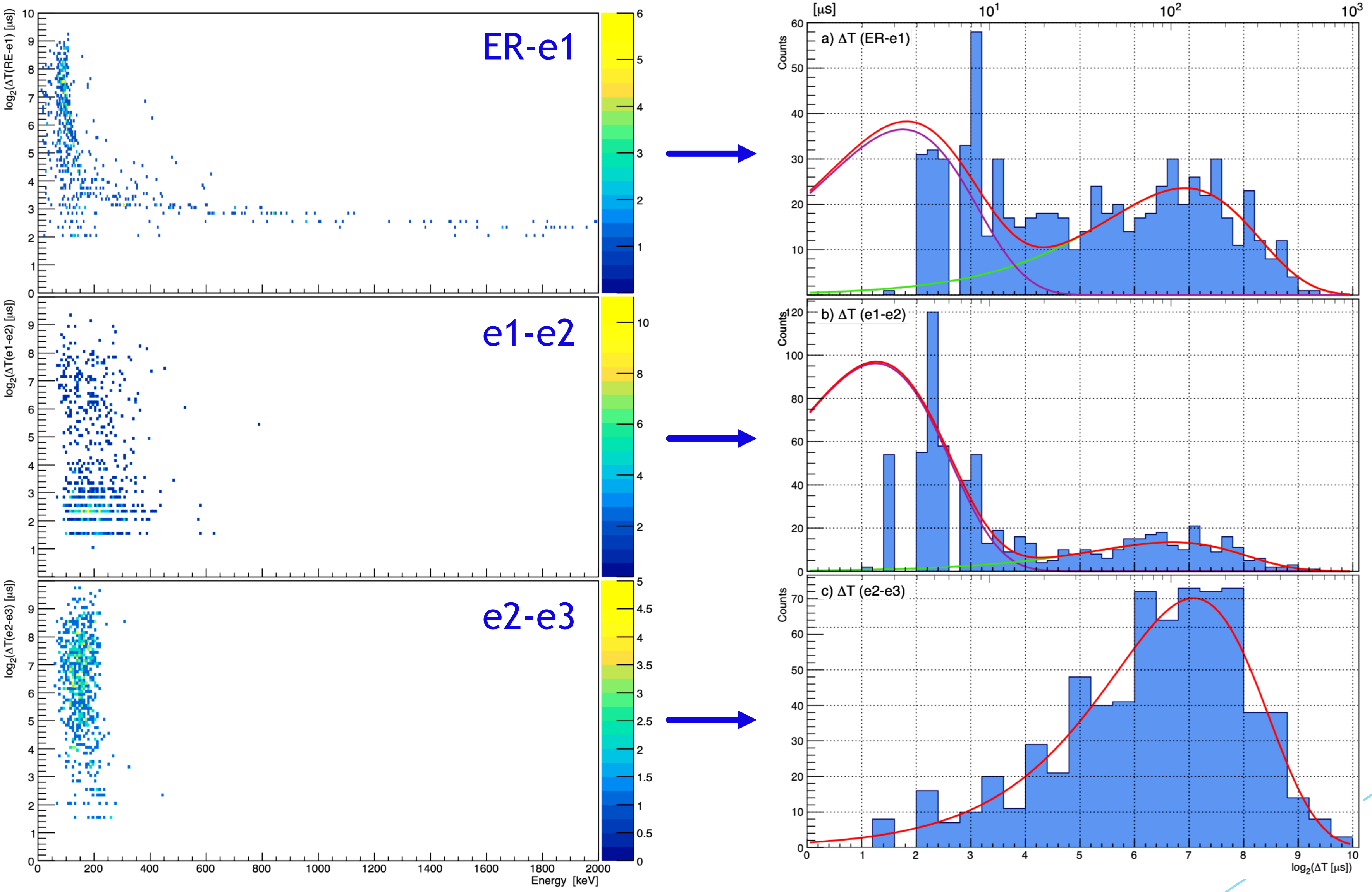
^{255}No : 4 Isomeric states





- 60 events
- Too scarce statistics in coincident gamma spectrum to conclude on their configuration

^{255}No : Cascades of 3 isomers



Measured properties :

$T_{1/2}^{4th}$ = 5 ± 1 µs
E_{DSSD} : Pile-up default
E_{tot}^{*} > 2430 keV

$T_{1/2}^{3rd}$ = 92 ± 13 µs
E_{DSSD} ≥ 130
E_{tot}^{*} ≥ 1430 keV

$T_{1/2}^{2nd}$ = 2 ± 1 µs
E_{DSSD} ≥ 400
E_{tot}^{*} ≥ 1230 keV

$T_{1/2}^{1st}$ = 86 ± 8 µs
E_{DSSD} ≥ 225 keV
E_{tot}^{*} ≥ 225 keV

^{255}No : Interpretation

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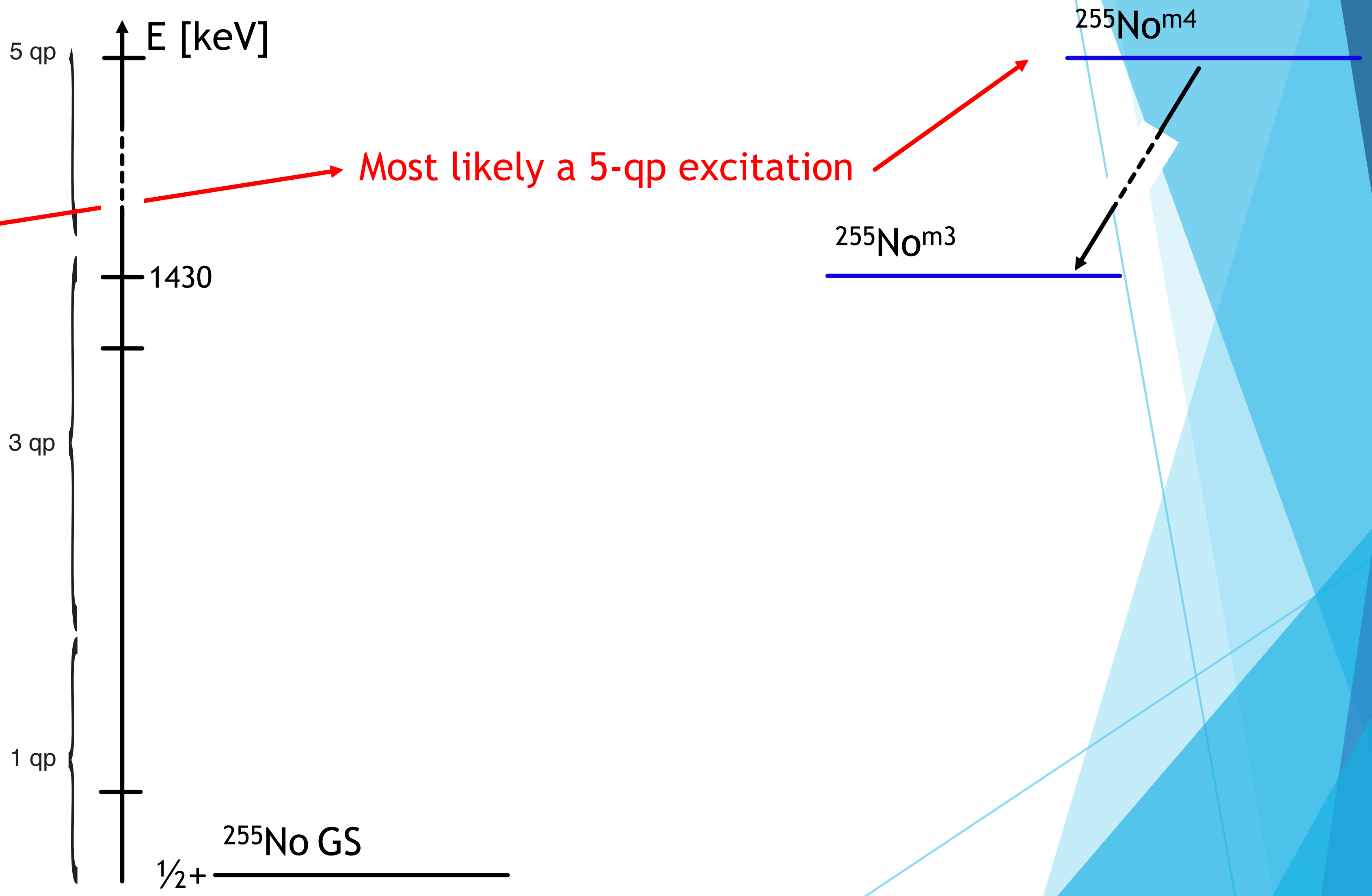

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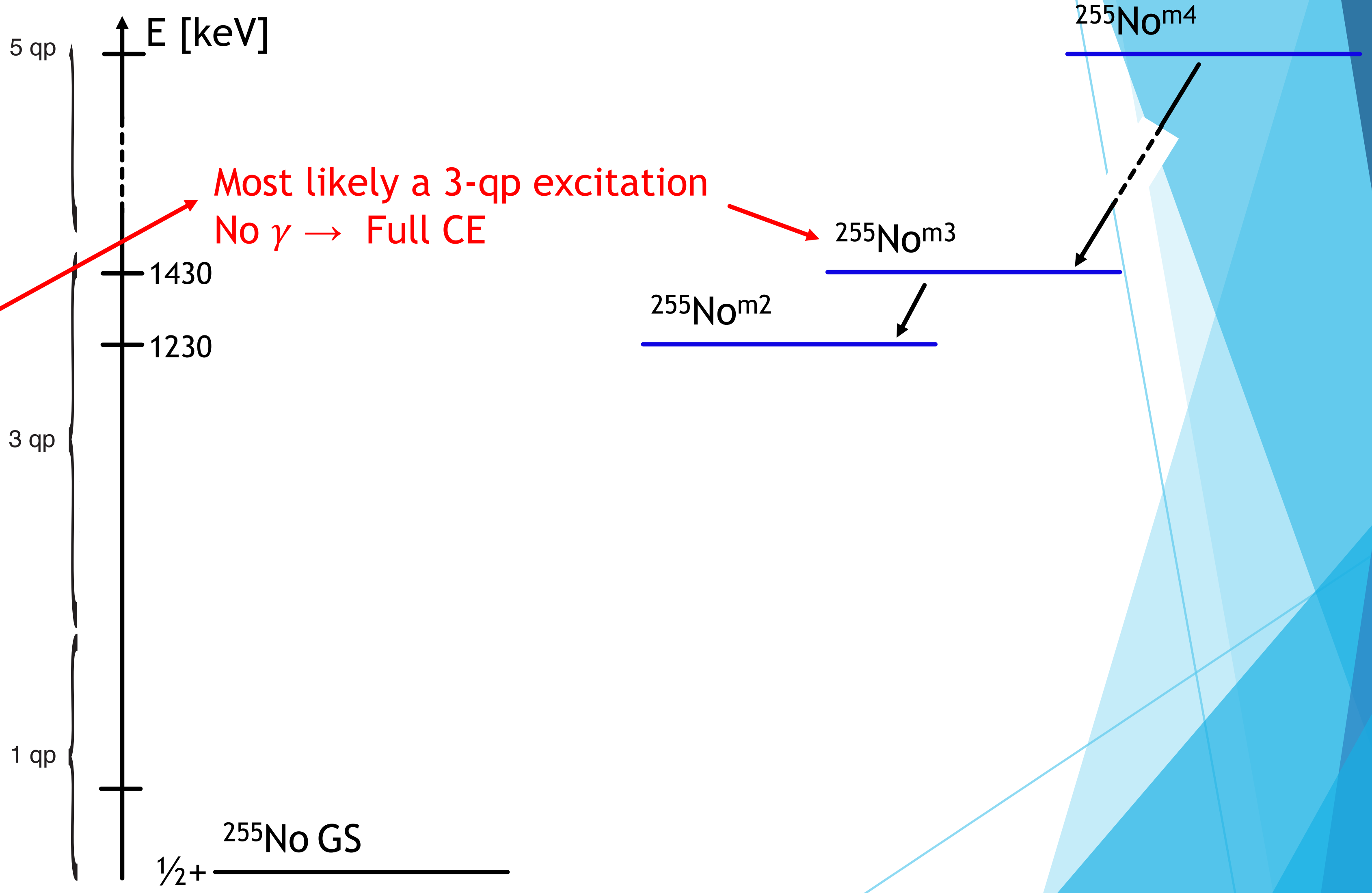

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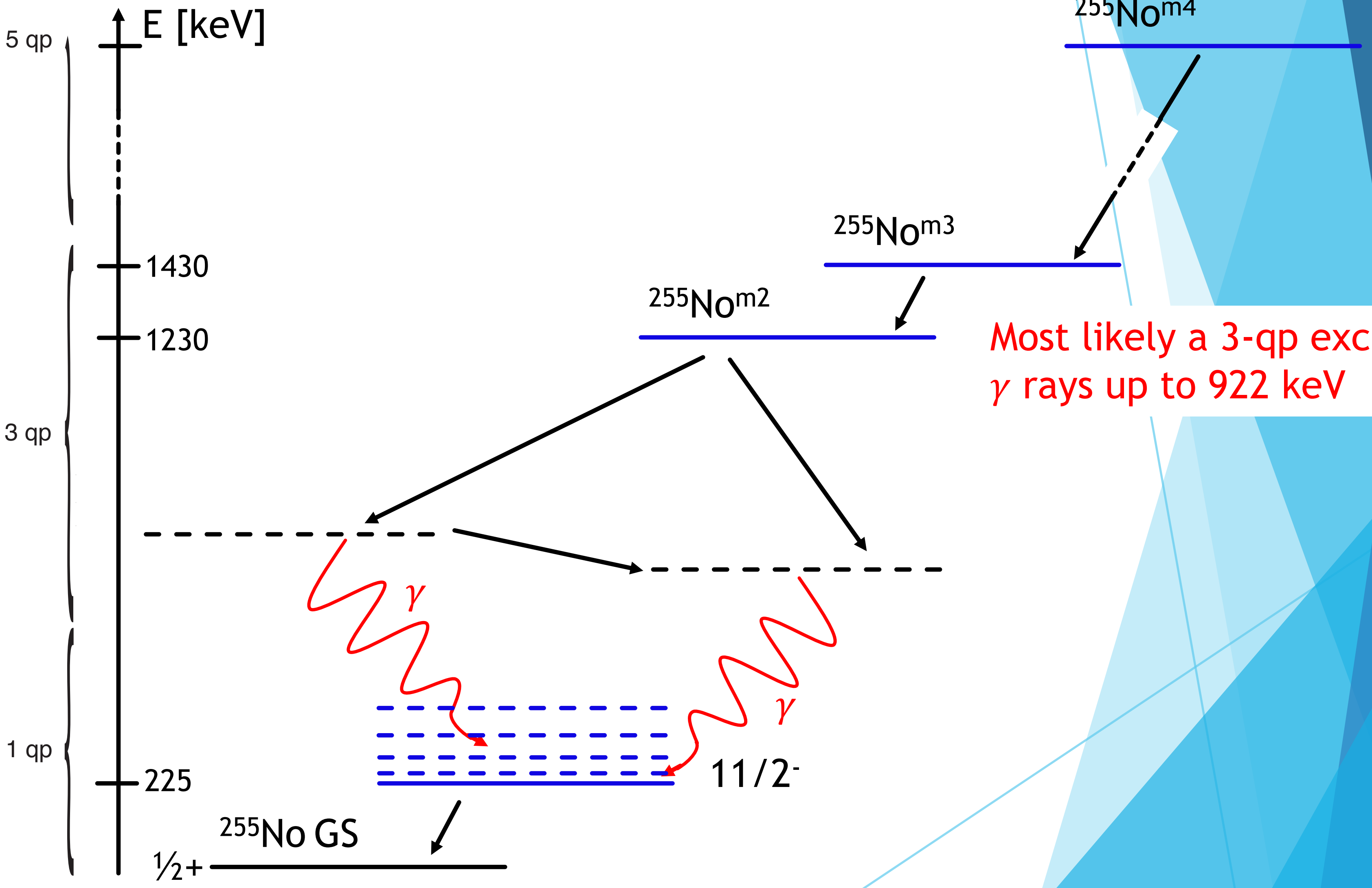

Most likely a 3-qp excitation
γ rays up to 922 keV

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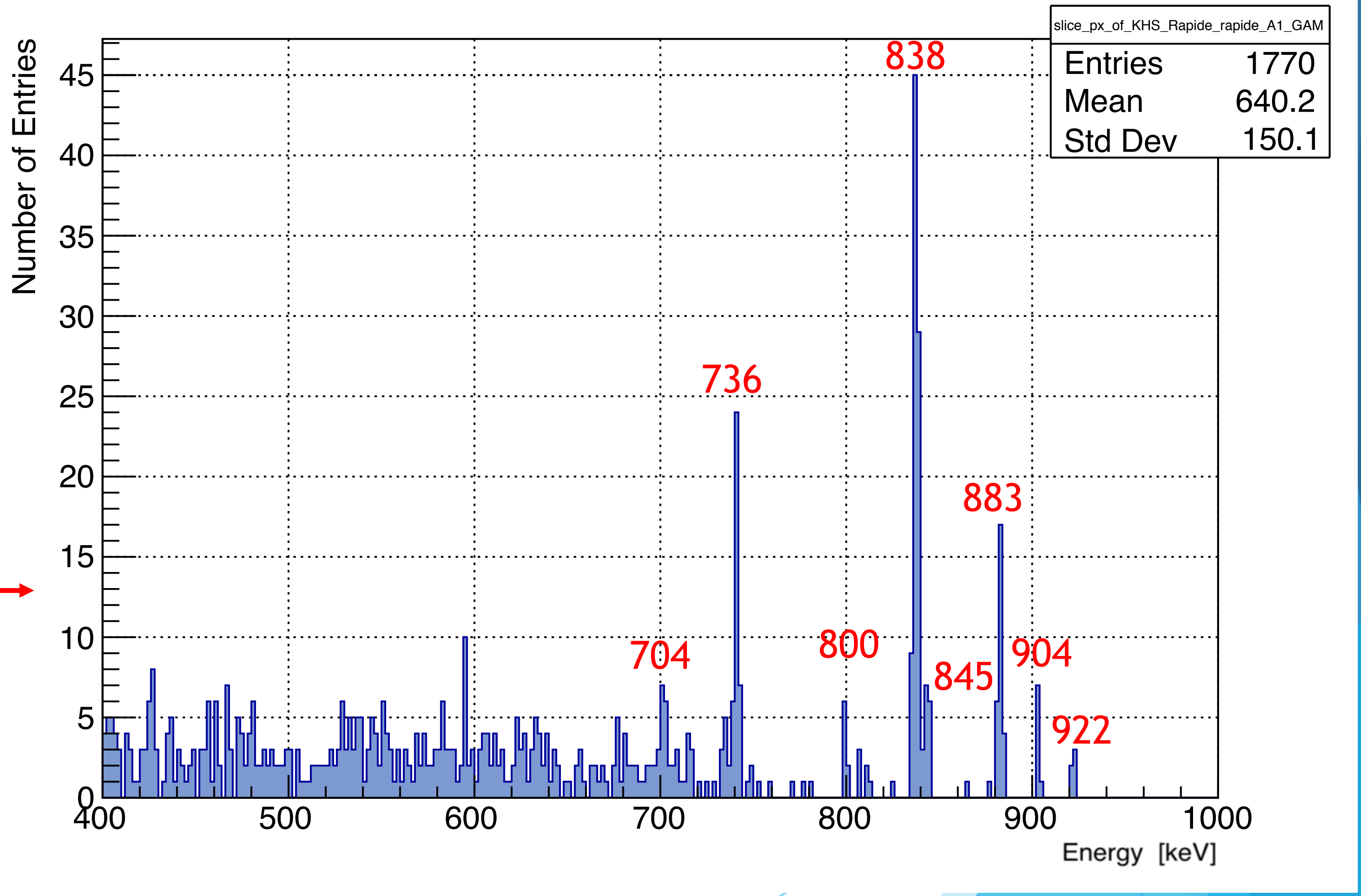
Coincident γ rays



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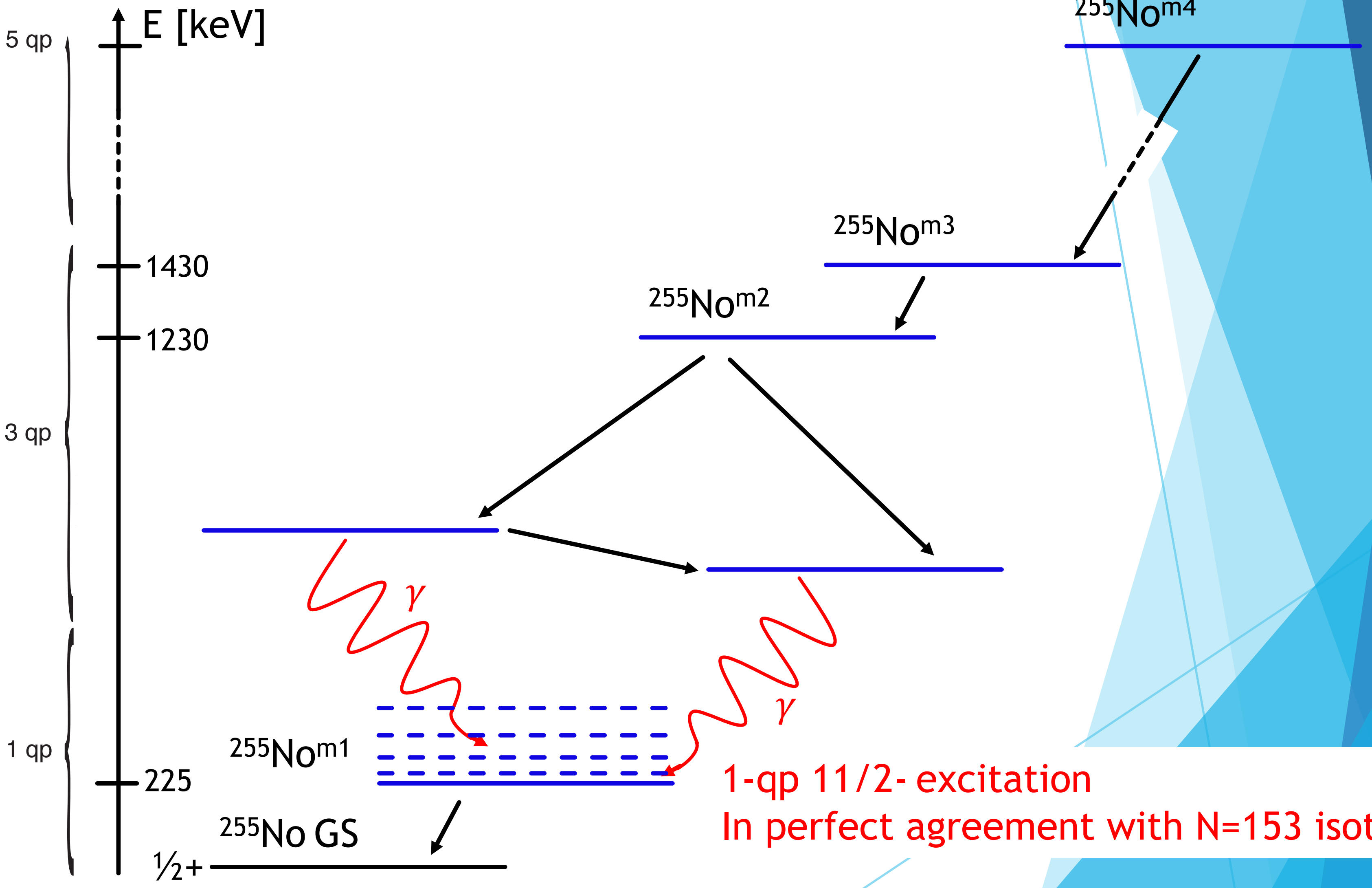

1-qp 11/2- excitation
In perfect agreement with N=153 isotones

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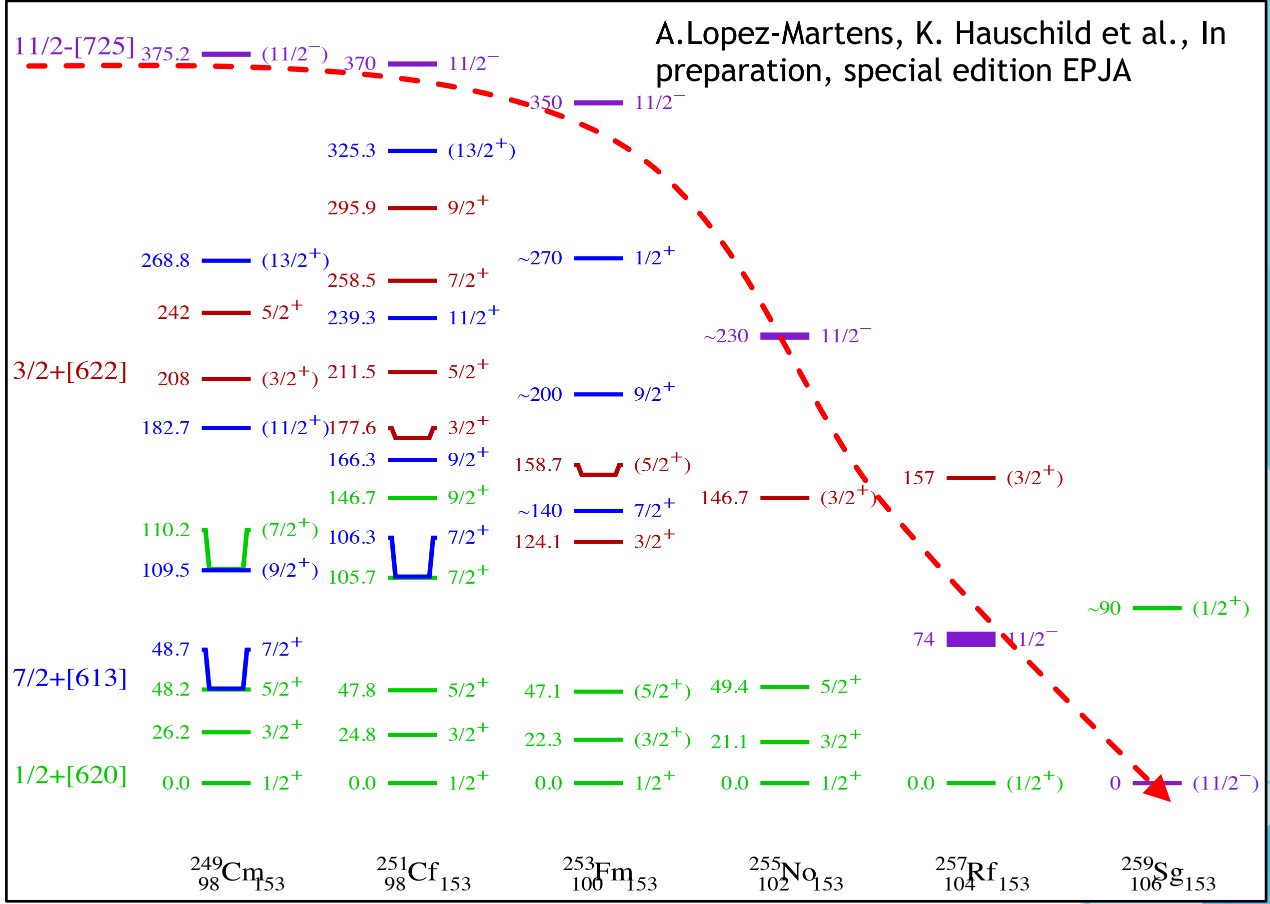

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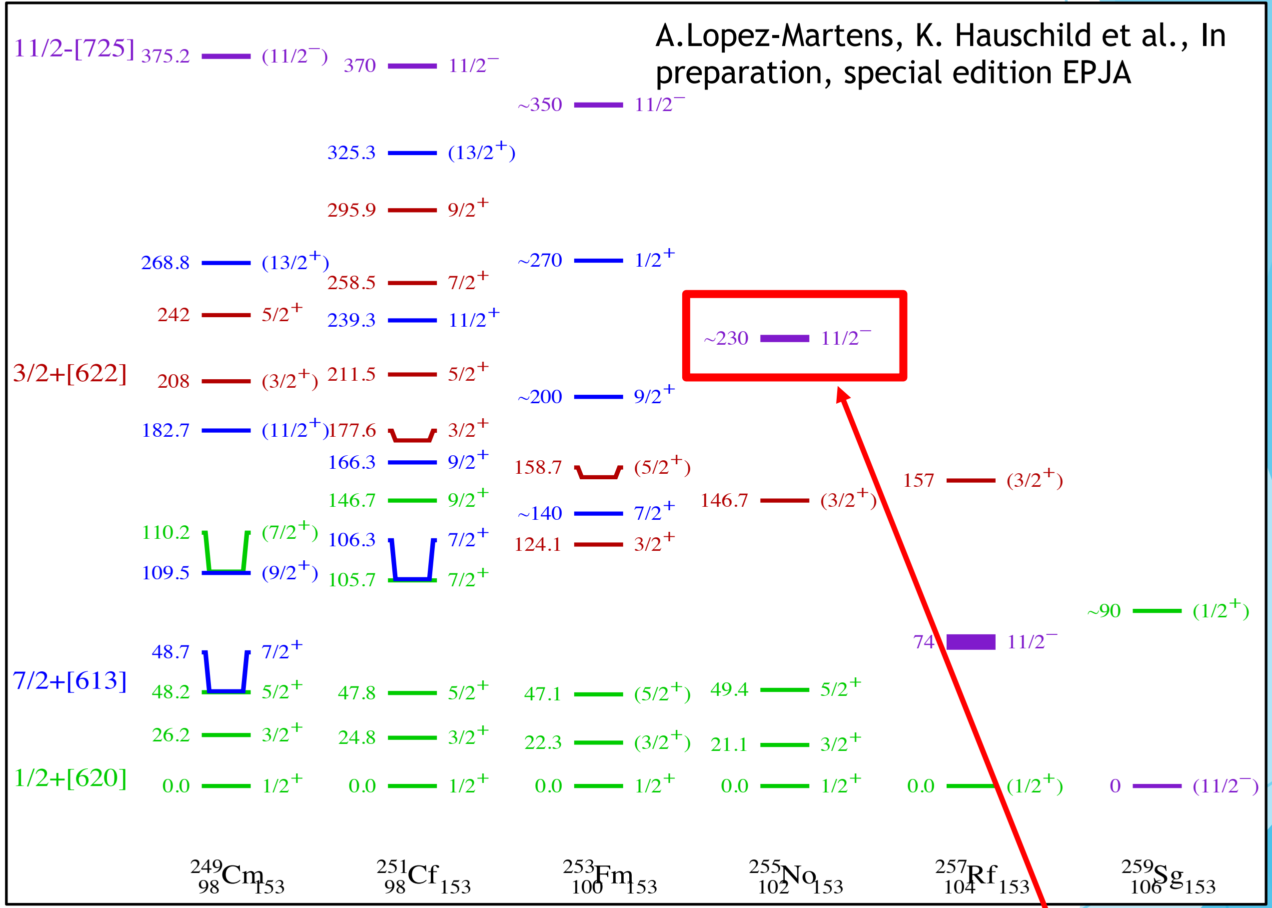

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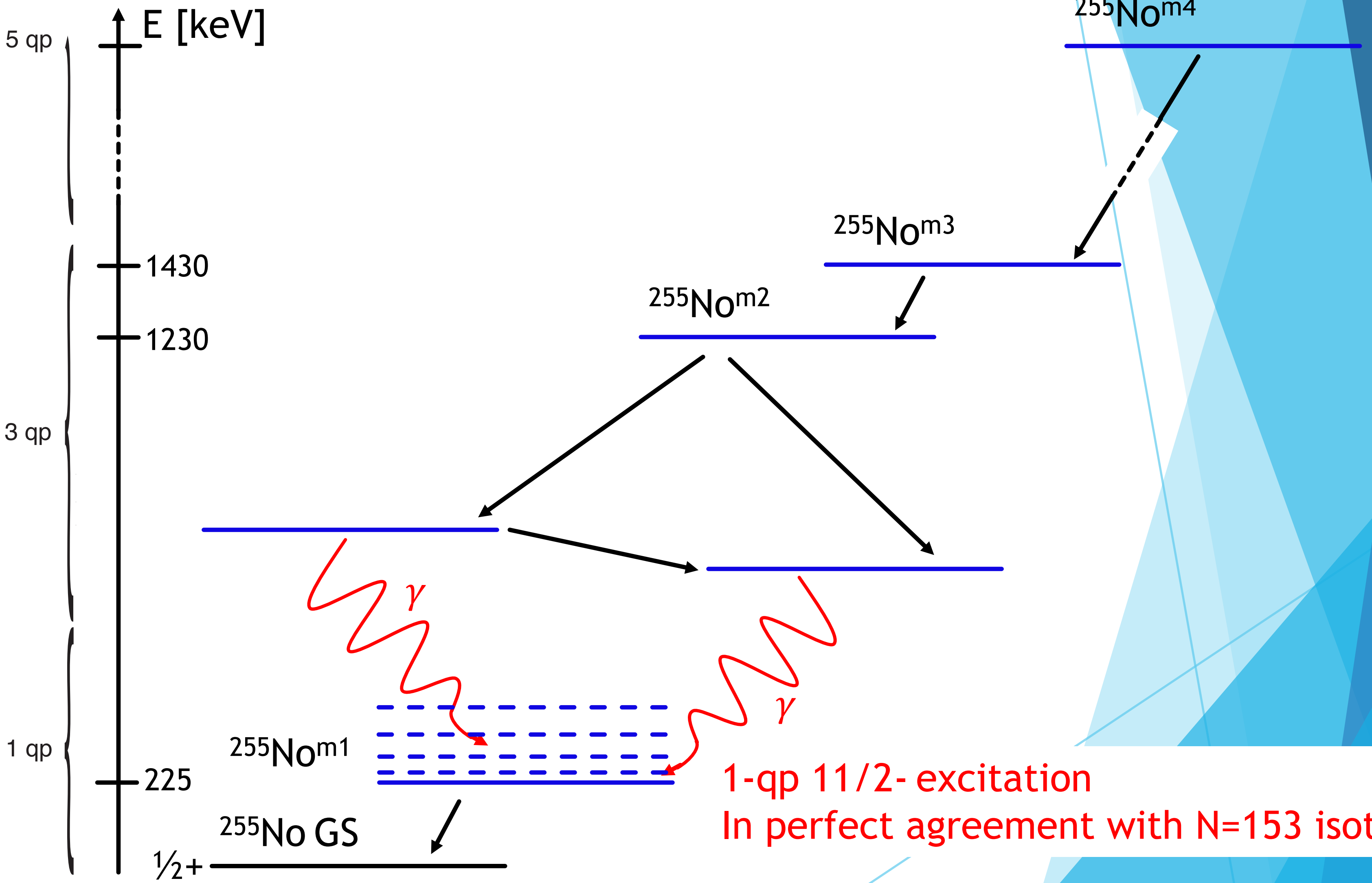

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Summary

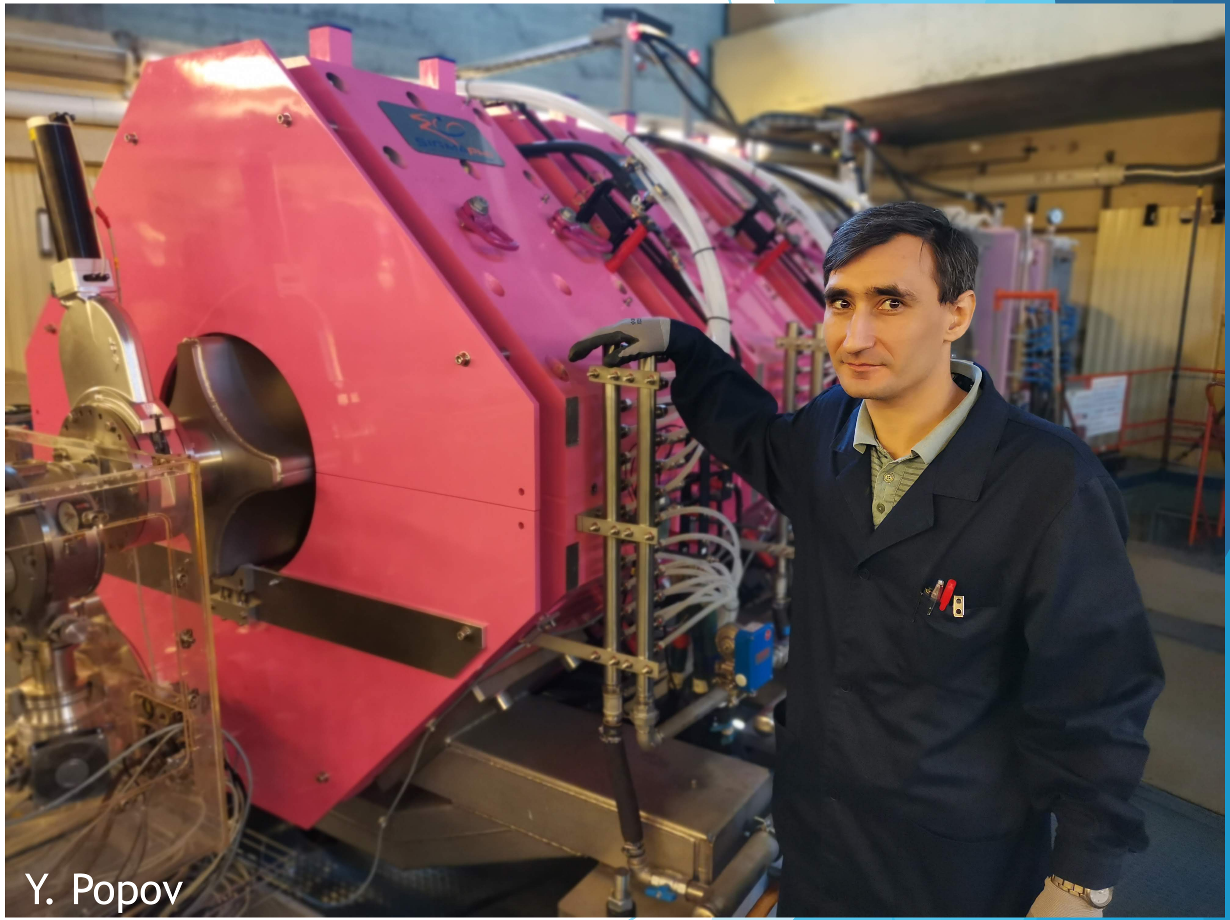
- First spectroscopic studies of ^{255}No and ^{256}No

- 4 isomeric states identified in ^{255}No

- ^{22}Ne + ^{238}U → ^{256}No + 4n will be repeated with :
  - Digital electronic
  - Lower conversion electrons thresholds (<100 keV)
  - Higher intensities
  - Upgraded SHELS

- Upgrade of SHELS
  → Entrance quadrupole-triplet upgraded
  → Increased transmission especially for the very asymmetric reactions

- SHEXI project (international ANR)
  Super Heavy Elements X-rays Identification
  → Increased X-rays / CE detection efficiency



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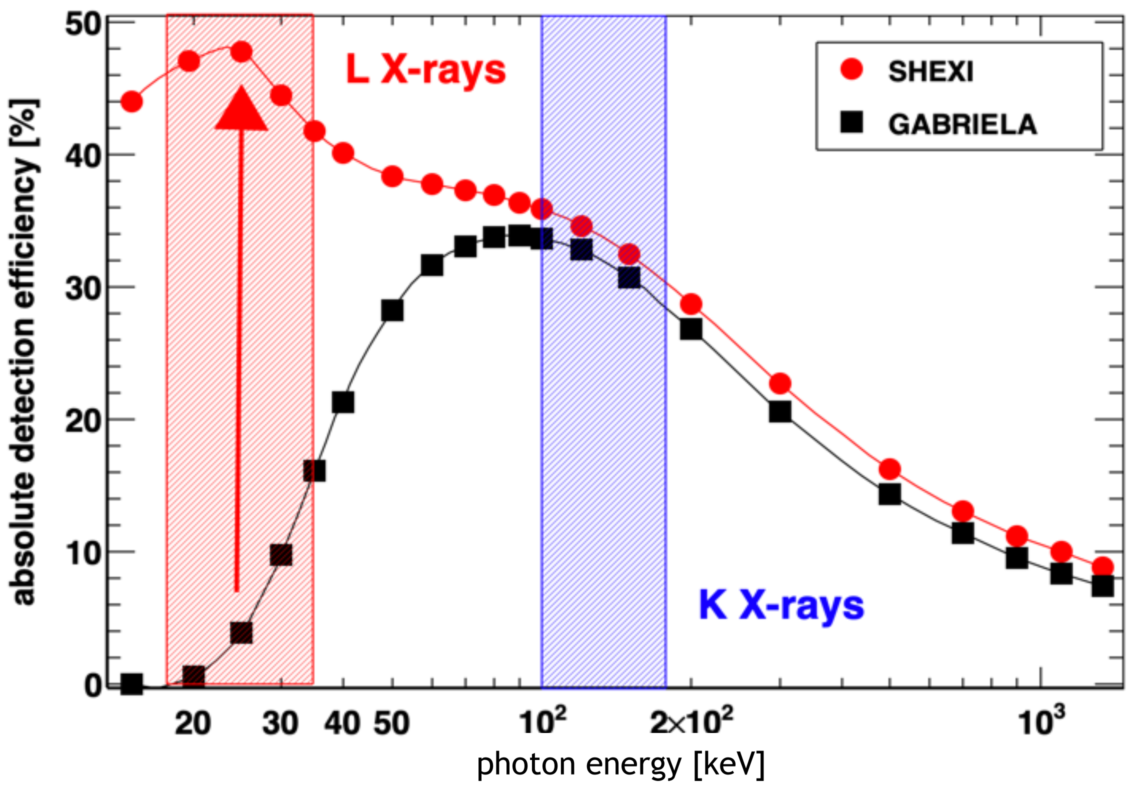


Collaborators :

- IN2P3 : B. J. P. Gall, A. Lopez-Martens, O. Dorvaux, K. Hauschild, M. Forge, R. Chakma, Z. Asfari
- GANIL : J. Piot
- FLNR : A. V. Yeremin, M. L. Chelnokov, V. I. Chepigin, A. V. Isaev, O. N. Malyshev, A. G. Popeko, Y. A. Popov, A. A. Kuznetsova, A. I. Svirikhin, E. A. Sokol, M. S. Tezekbayeva, R. Mukhin
- Chinese Academy of Science : B. Ding, Z.Liu, F. Zhang

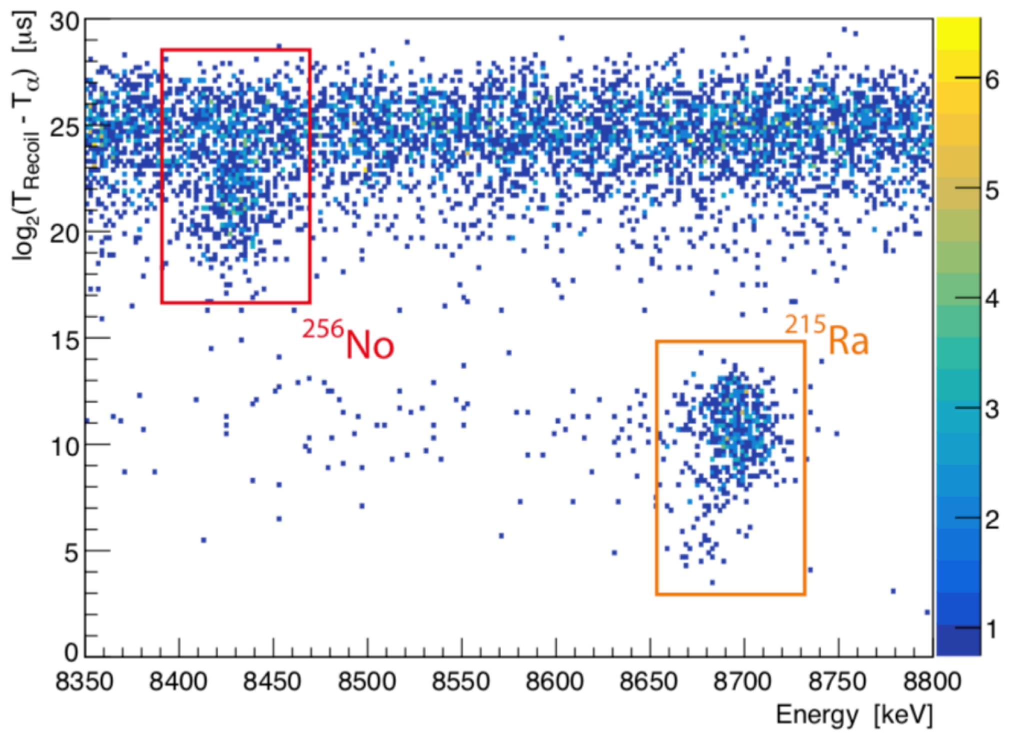
Thank you

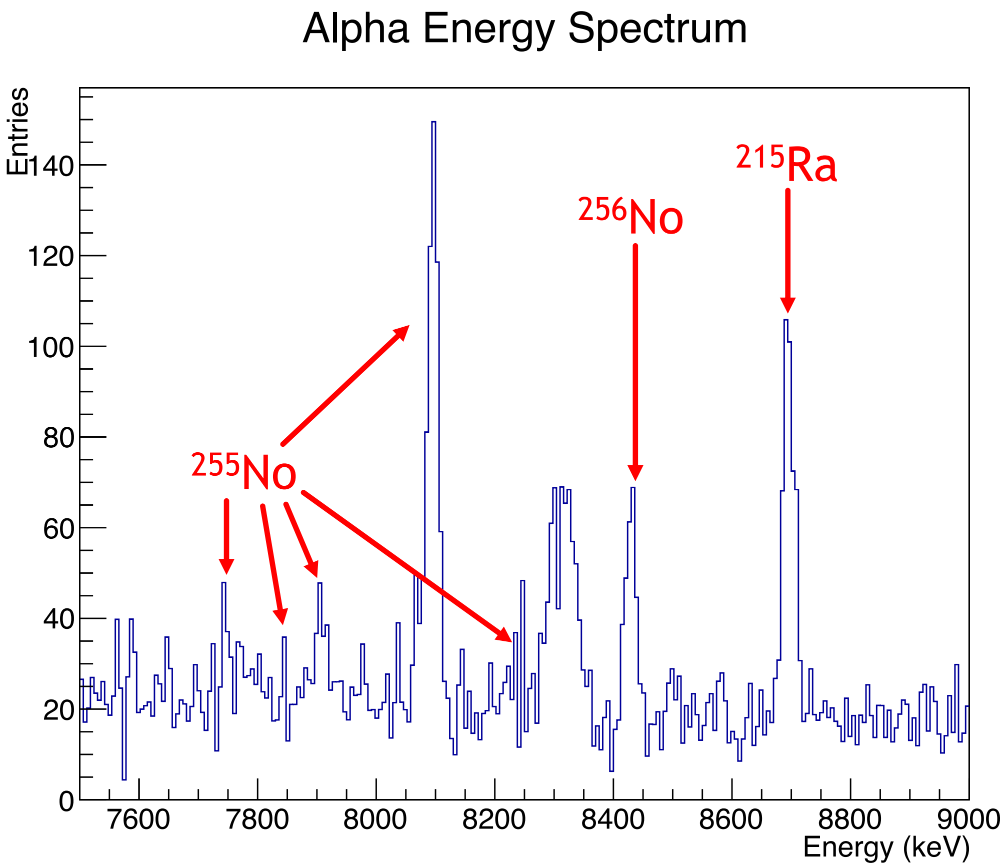
GS Properties : Decay Energy

$^{22}Ne + ^{238}U \rightarrow ^{260-x}No + xn$

- ^{255}No : 7748 ± 2 keV
  7843 ± 4 keV
  7909 ± 2 keV
  8101 ± 1 keV
  8232 ± 8 keV

- ^{256}No E = 8444 ± 10 keV.
  [9] E= 8447 ± 3 keV.
  → Corrected by the method developed by W. J. Huang and G.Audi





[9] M. Asai et al., JAEA-Review 2016-025 (2016) pp. 9-10.

Calibration

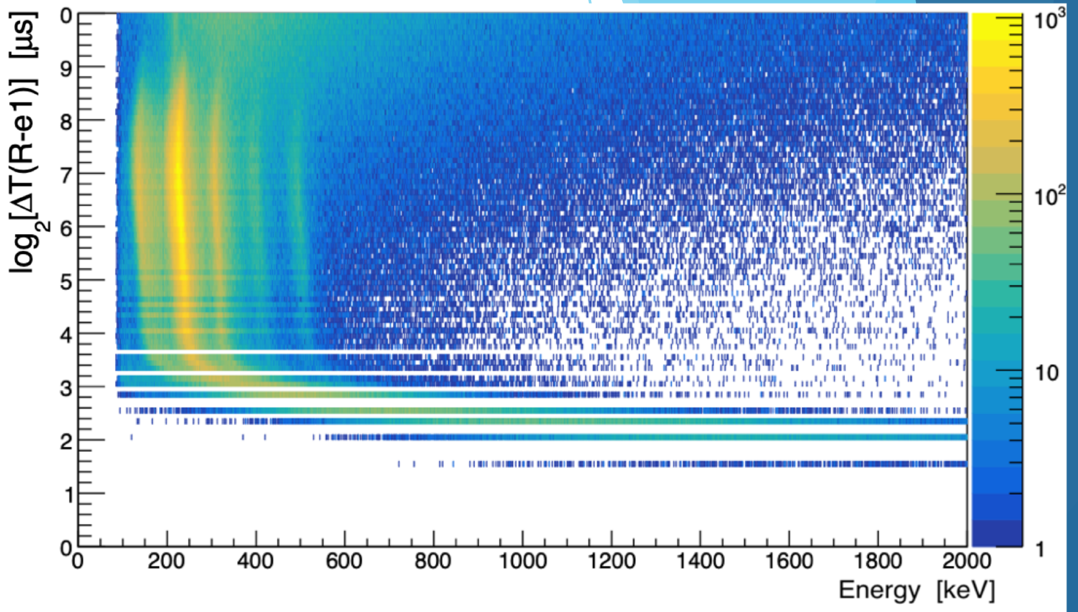
- Clock of the acquisition system 1µs
- Charge collection time up to 7-8µs

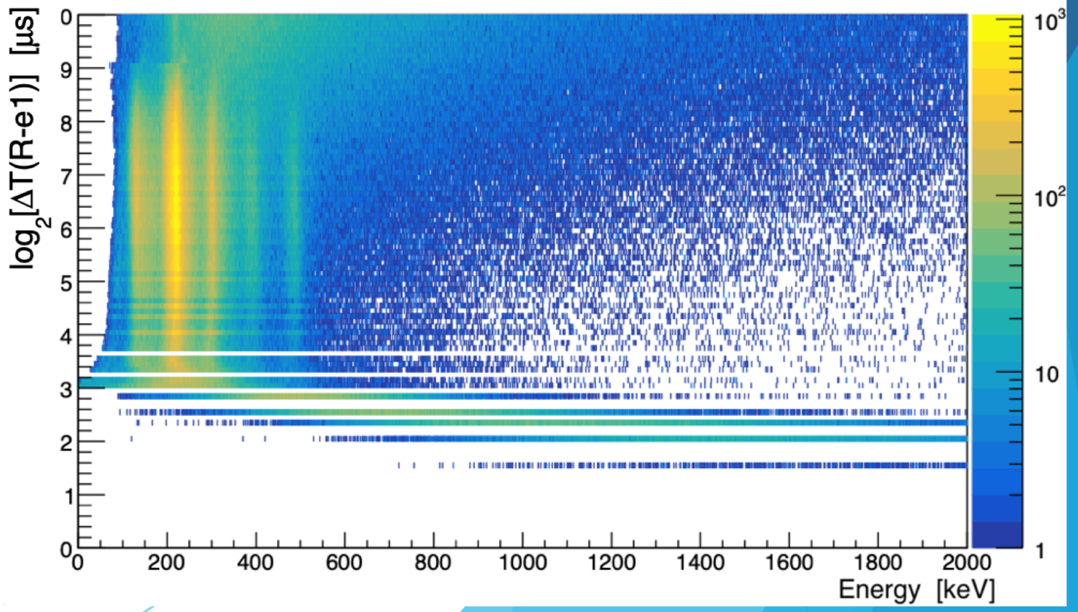
  → Pilup effects for very fast decays

- The electron signal may be piled on the tail of the implantation signal leading to an apparent higher energy.

- An energy correction process could be applied in a time range between log2(ΔT [µs]) = 9 and 3
- Impossible to correct this effect below 2^3 µs

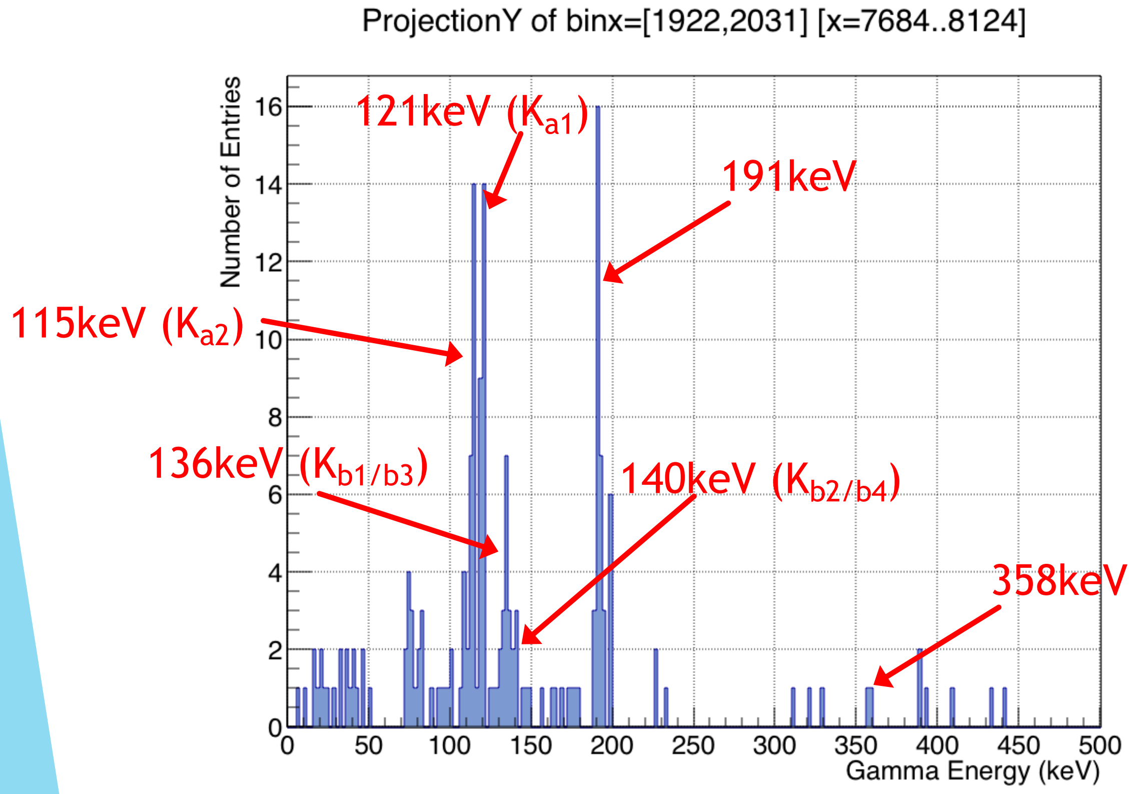
	< 8 µs	≥ 8 µs
Energy		
Time		





Results : ^{251}Fm

- Through the decay of ^{255}No we can see the X-rays of ^{251}Fm
- These results are in perfect agreement with the study from M. Asai (2011) [9] or K. Rezynkina (2018) [12]



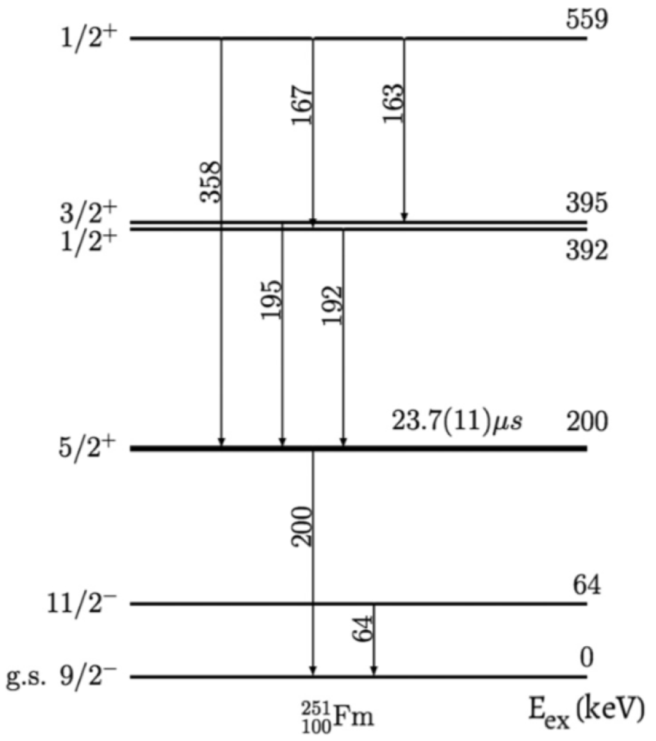


FIG. 2. A simplified level scheme depicting the observed transitions in ^{251}Fm populated in α decay of ^{255}No.

[9] M. Asai, K. Tsukada, H. Haba and al. - PHYSICAL REVIEW C 83, 014315 (2011)
[12] K. Rezynkina, A. Lopez-Martens, K. Hauschild and al. - PRC 97, 054332 (2018)

Experiment

Experimental Conditions

$^{22}Ne + ^{238}U \rightarrow ^{260-x}No + xn$

$^{48}Ca + ^{208}Pb \rightarrow ^{256-x}No + xn$

- Hot Fusion
- ^{255}No and ^{256}No produced
- April 2019
- 3 weeks of beamtime
- ^{238}U(M) Target (99,99%)
- ^{22}Ne Beam
- Intensity between 0.6 and 1.0 pμA
- Beam Energy 107-112 MeV

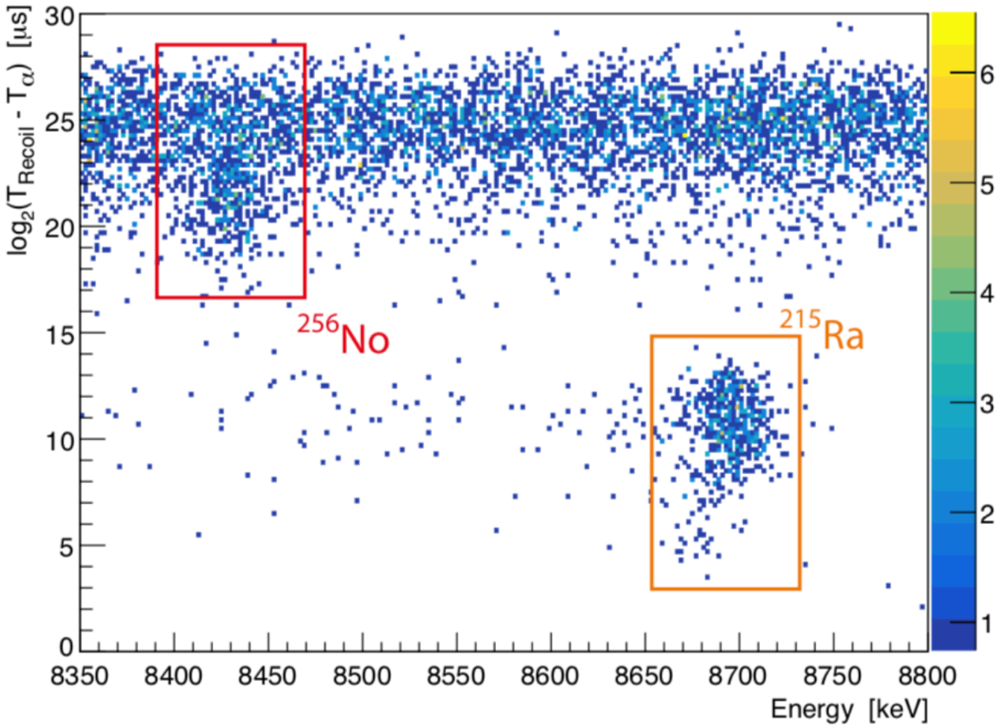
- Cold Fusion
- ^{254}No and ^{255}No produced
- November/December 2019
- 4 weeks of beamtime
- ^{208}Pb Target (99,99% pure)
- ^{48}Ca Beam
- Intensity between 0.4 and 0.5 pμA
- Beam Energy 225 MeV

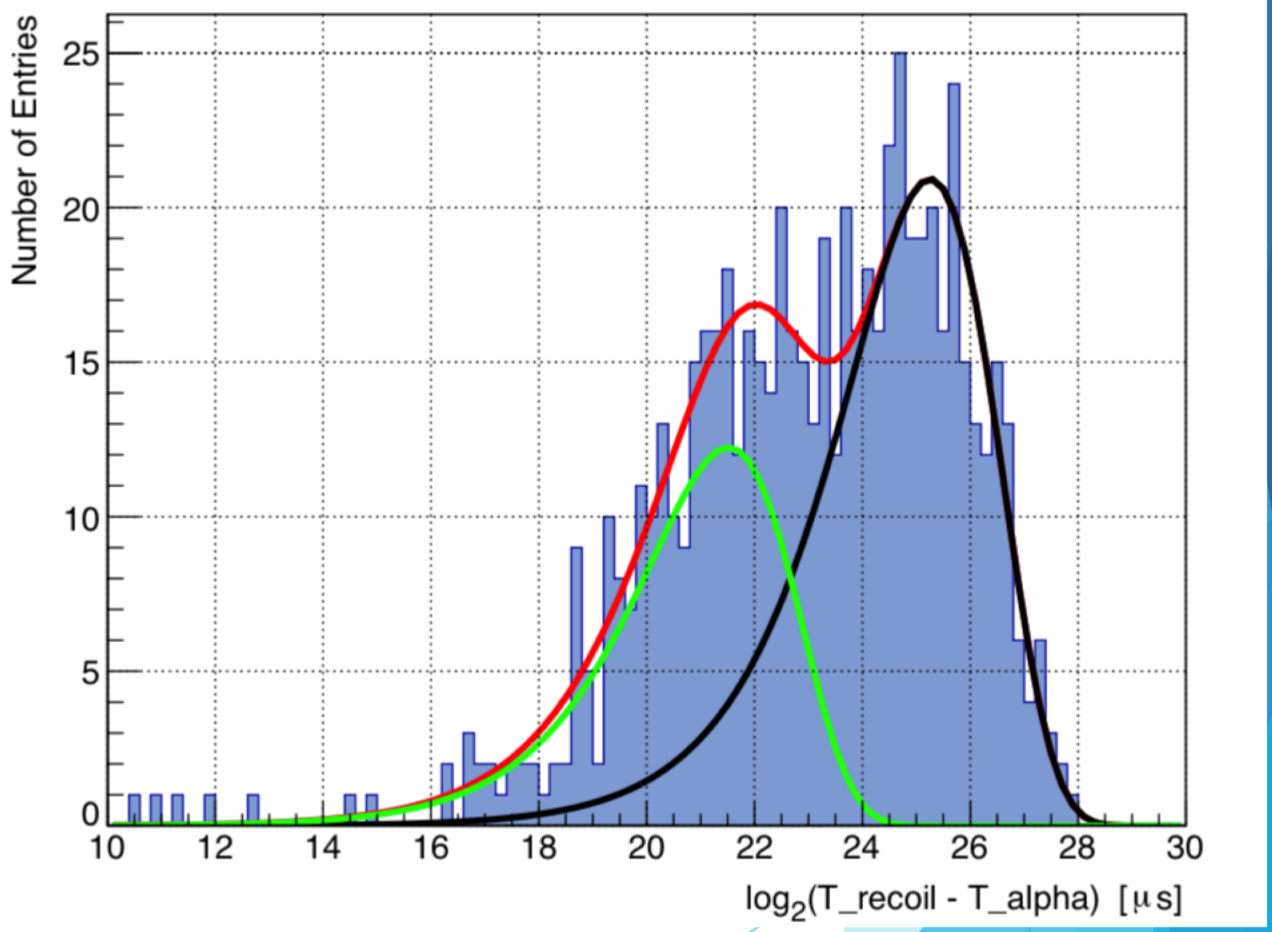
GS Properties : Lifetime

$^{22}Ne + ^{238}U \rightarrow ^{260-x}No + xn$

- Half-life of ^{256}No: $T_{1/2} = \frac{\ln(2)}{\lambda} = 2{,}79 \pm 0{,}18\ s$

  Literature half-life : 2,8 $\pm$ 0,3 s [9]





[10] M. Asai and al. - Physical Review C 83, 014315 (2011)