Competing radioactive decays from a high-spin isomeric state in Ta-158.

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Overview

Motivation

Experimental details

Recent analysis of ^{158}Ta

- Gamma-ray spectroscopy
- Competing radioactive decays

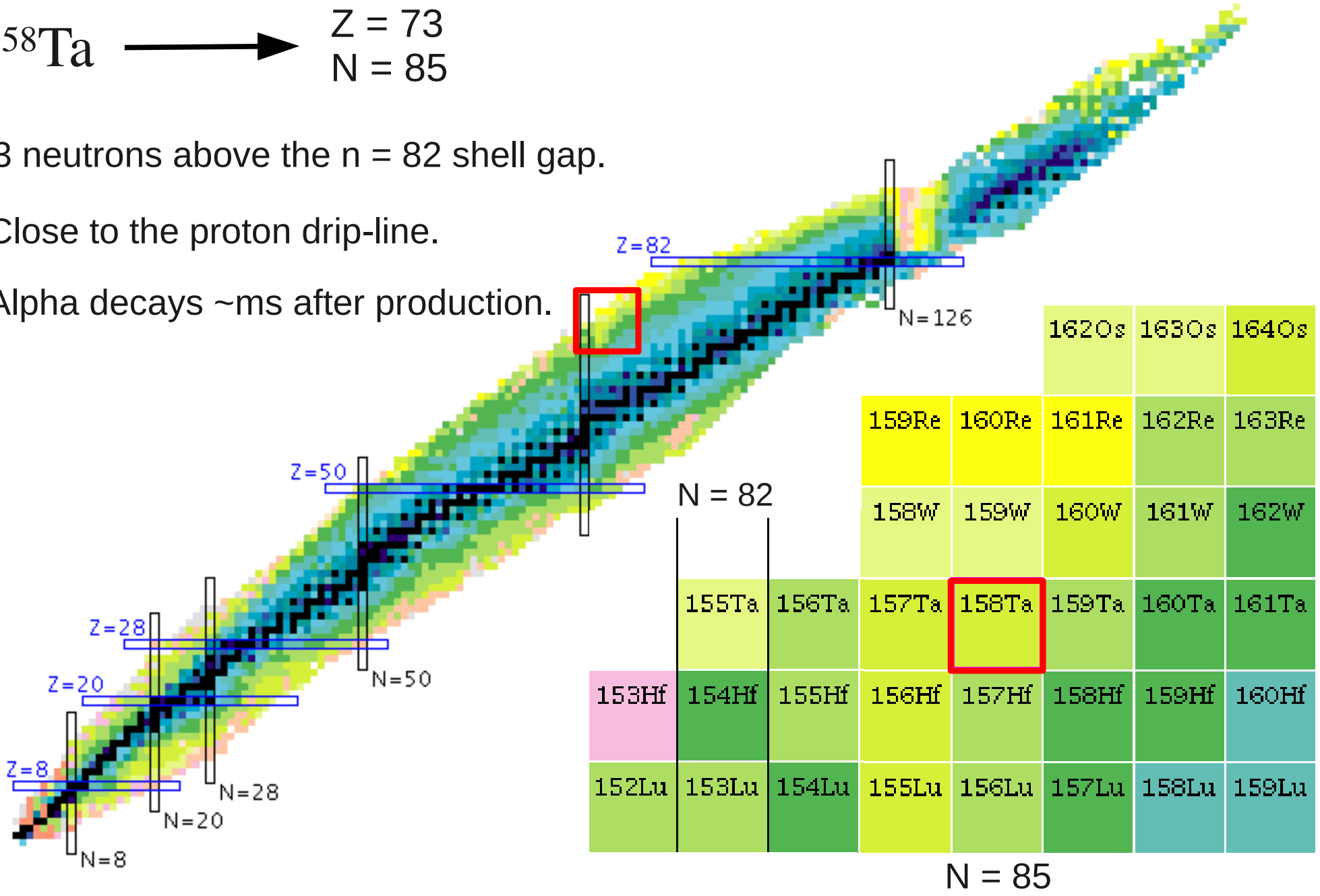
Further analysis

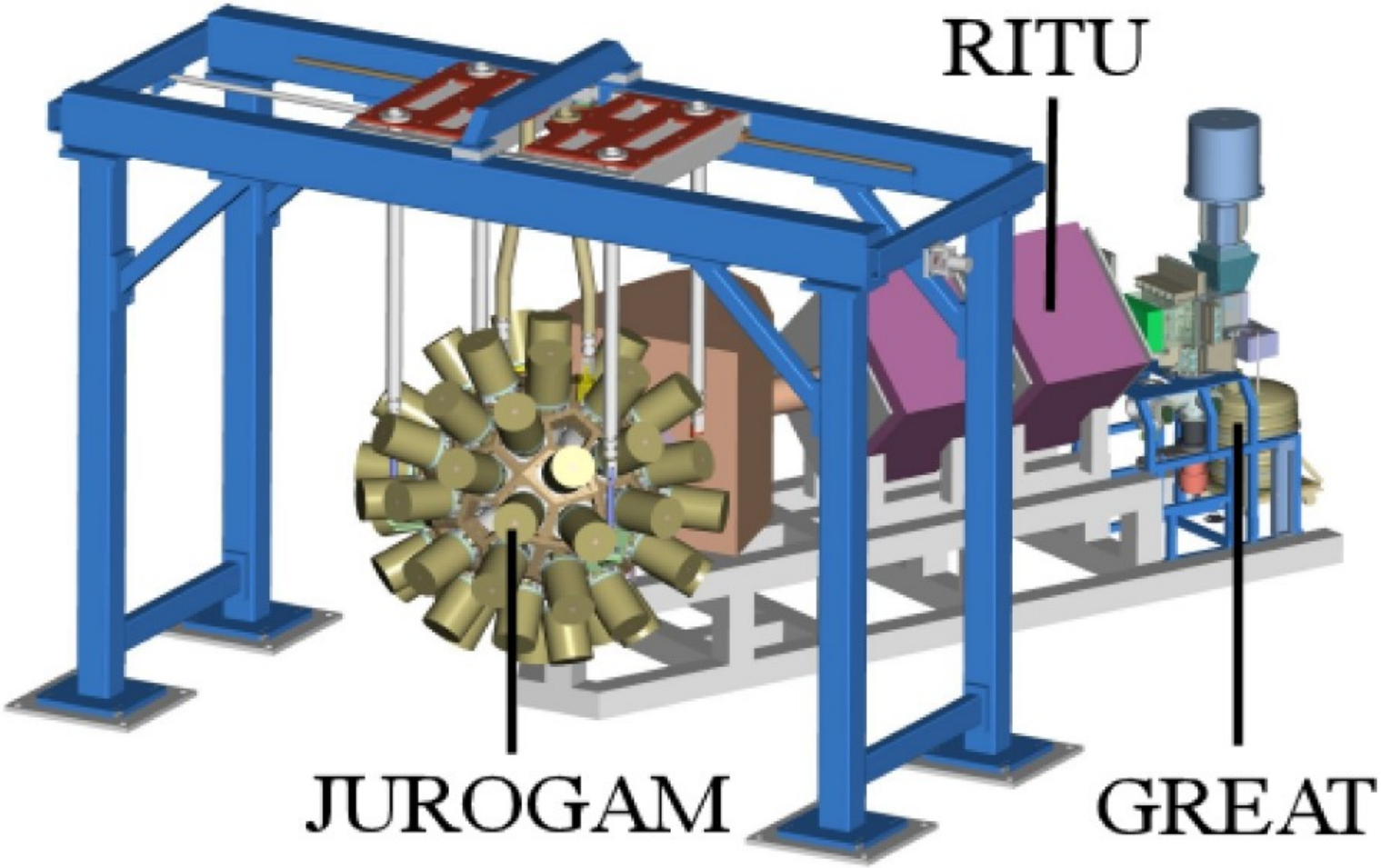
^{158}Ta ⟶ Z = 73, N = 85

3 neutrons above the n = 82 shell gap.

Close to the proton drip-line.

Alpha decays ~ms after production.

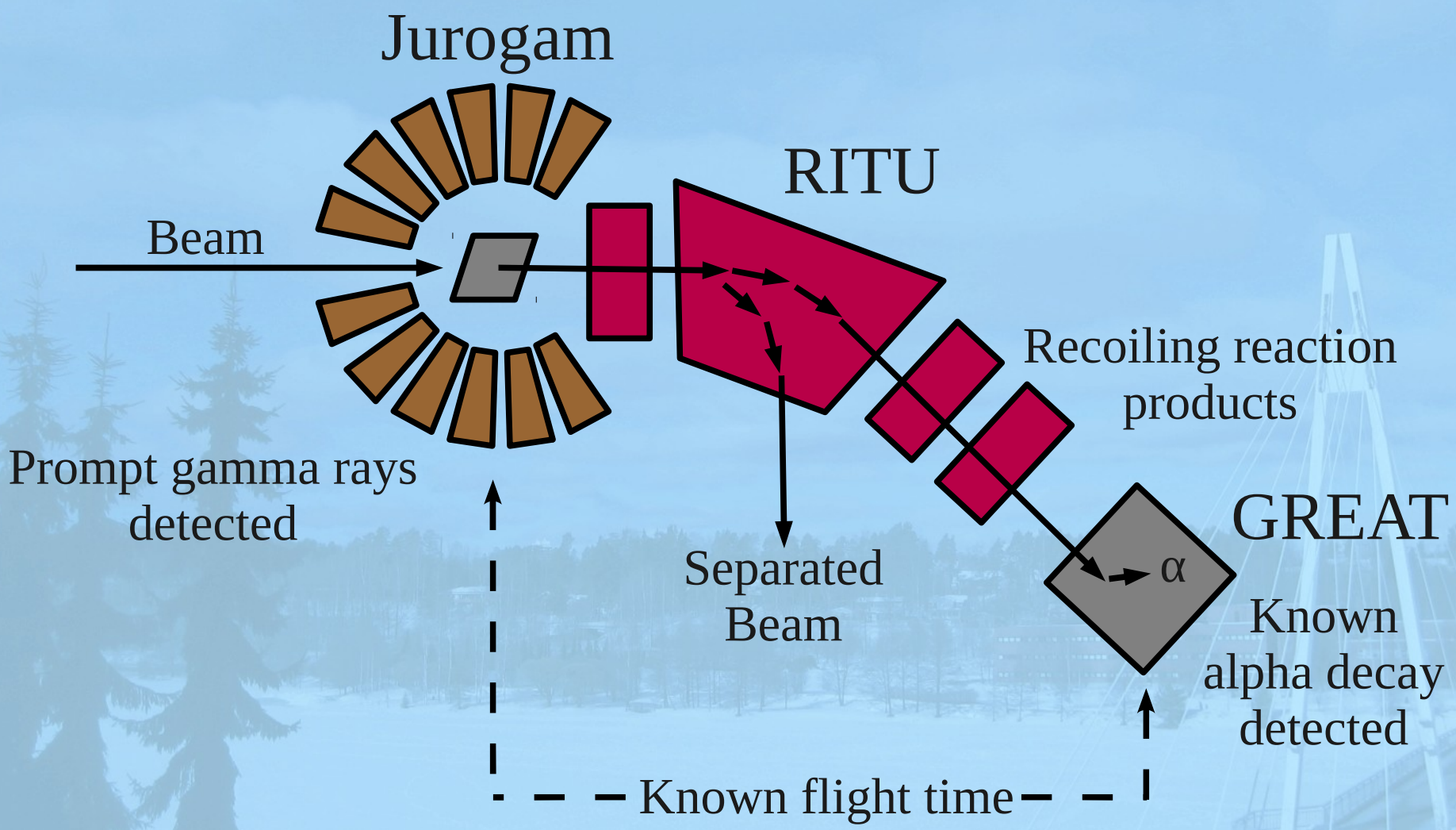




$^{102}Pd(^{58}Ni,pn)^{158}Ta$

(E_{beam} ~ 280 MeV)

Recoil-decay tagging (RDT)

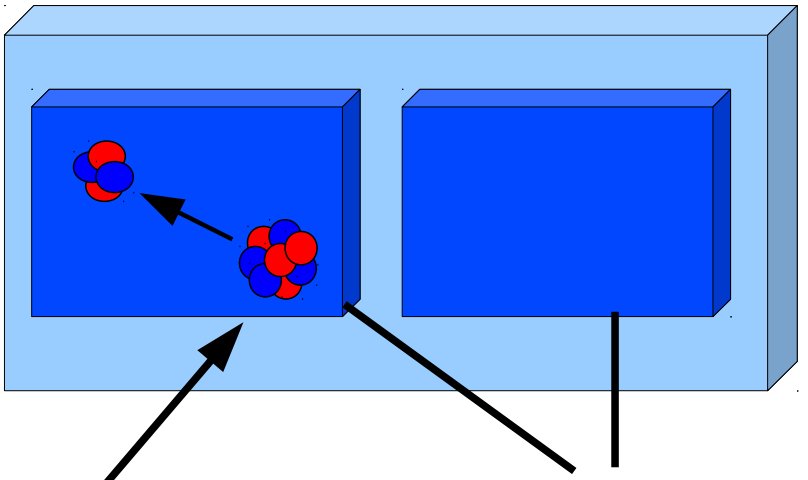


The GREAT Spectrometer

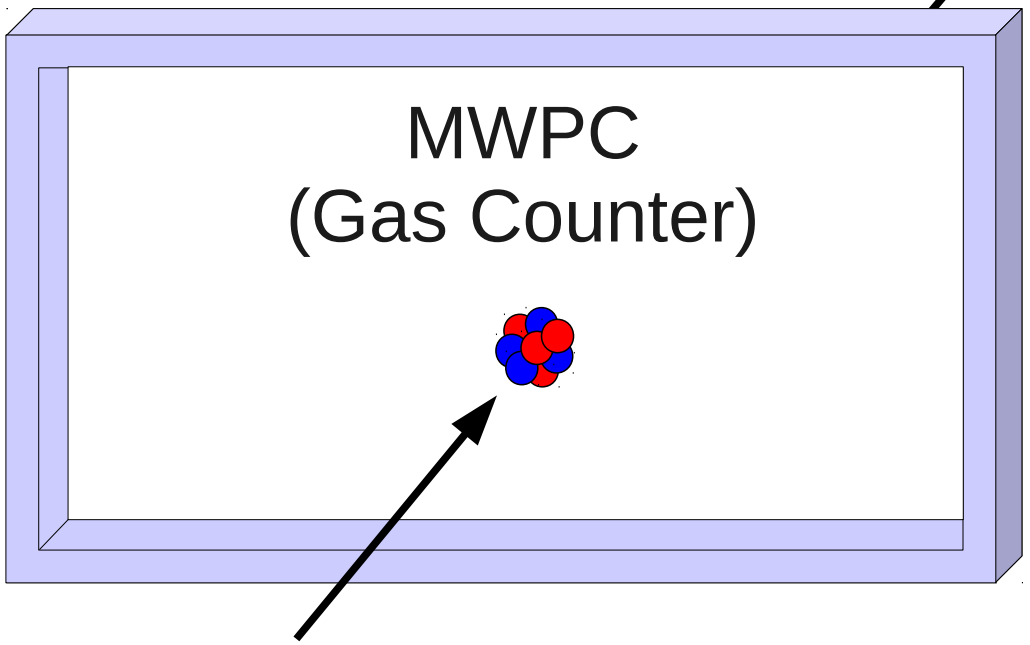
Two main roles in this work:

1. Recoil Identification

2. Spectroscopy of decays from isomeric states



DSSDs
(Silicon Strip Detectors)



MWPC – Distinguishes between recoils and decays

DSSDs – Identify recoils using decay properties

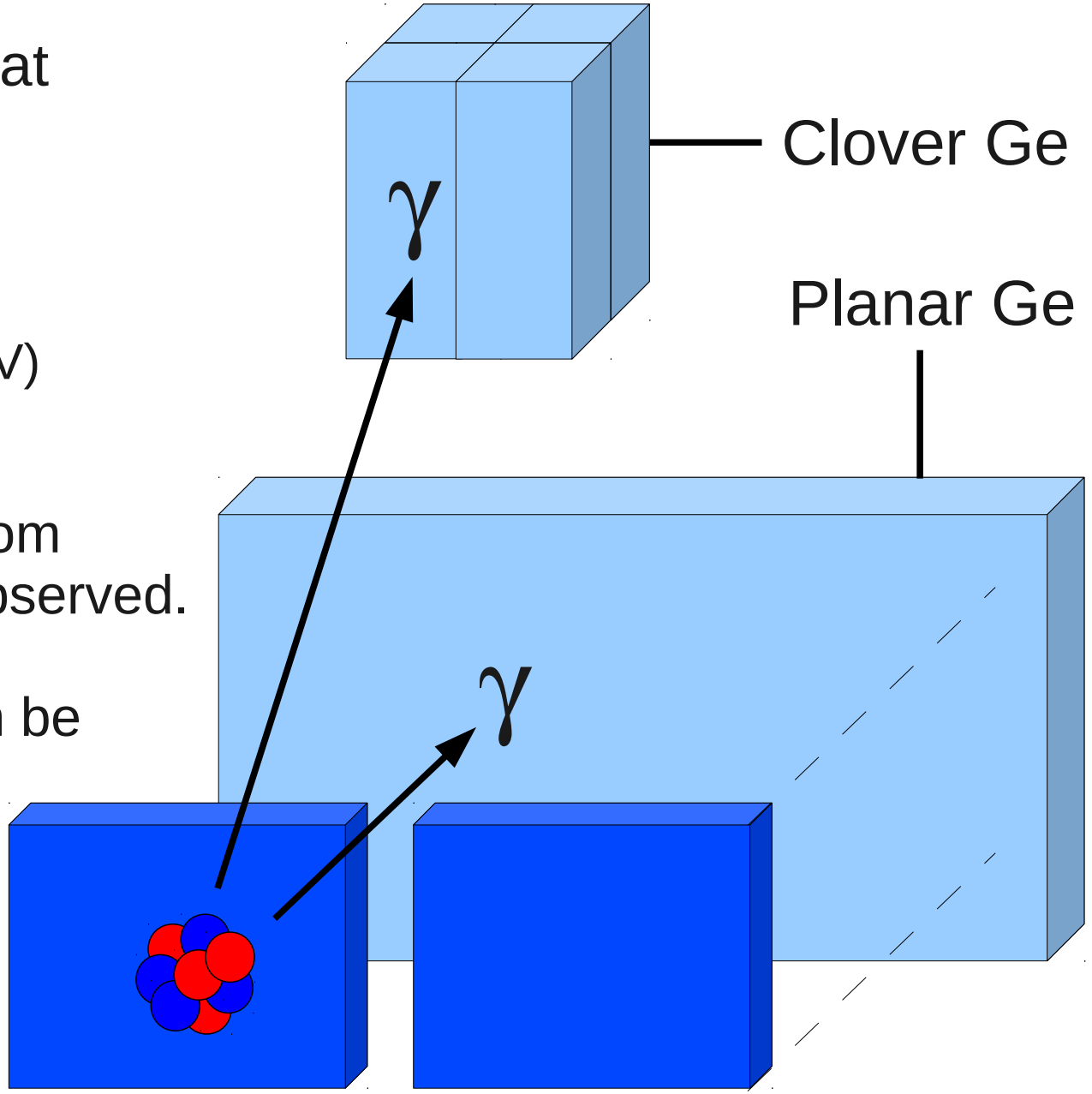
Germanium detectors at the focal plane:

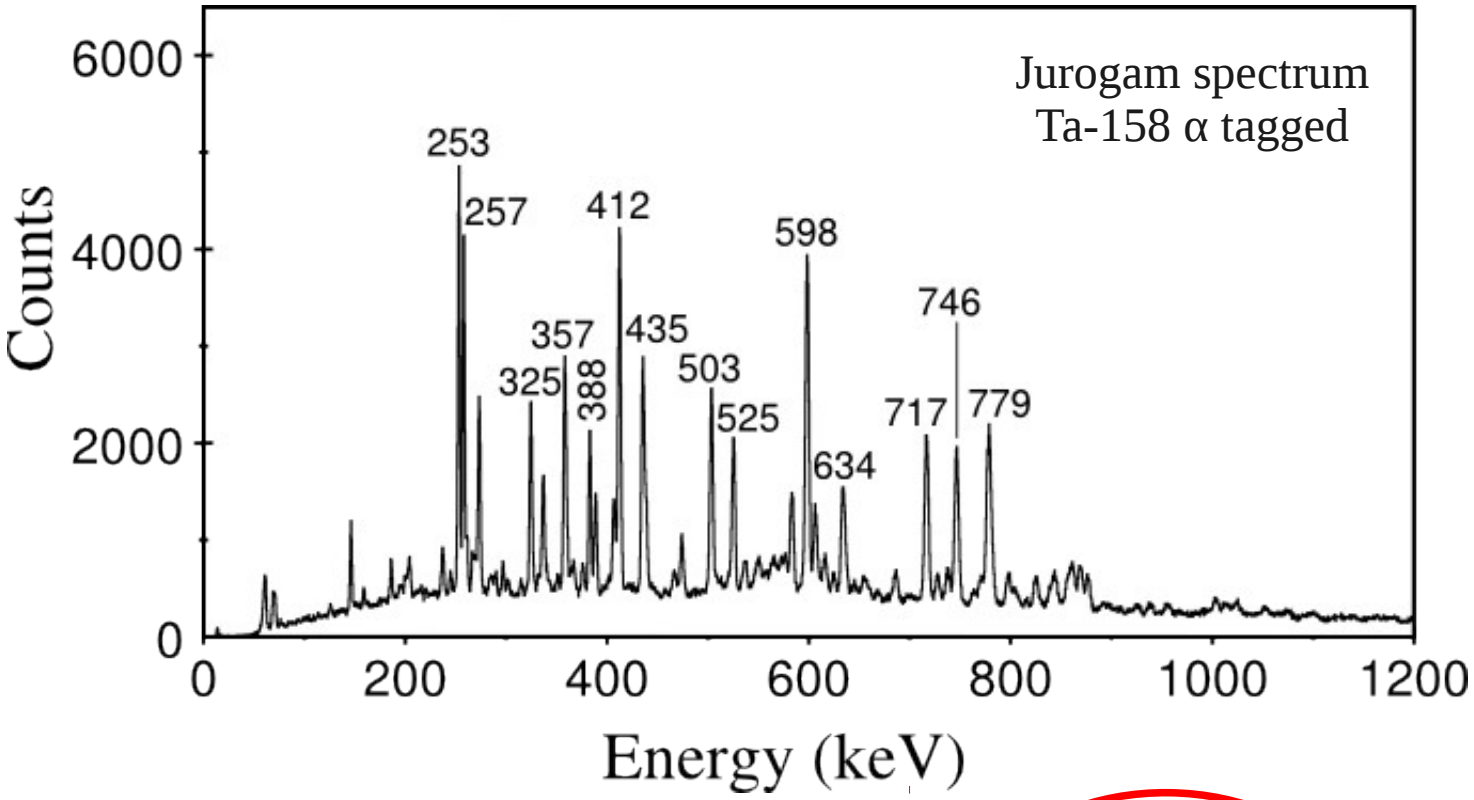
1. Planar (< 500 keV)

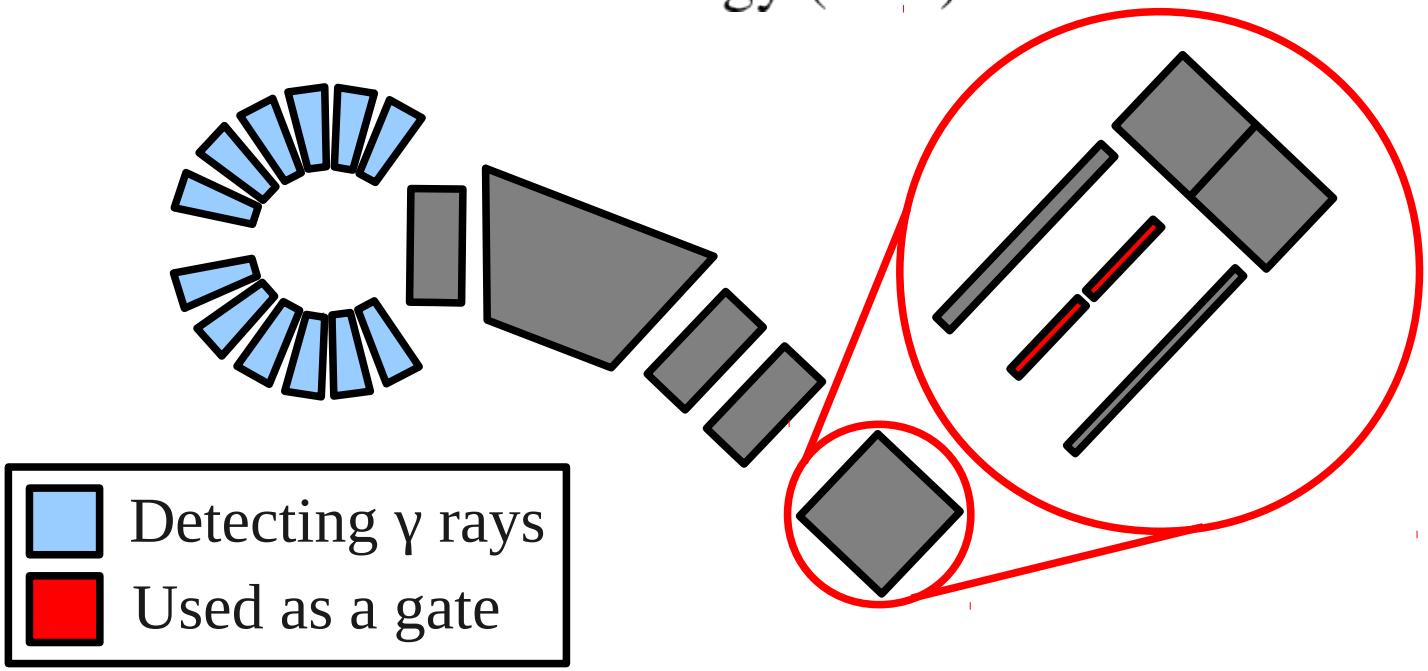
2. Clover (~100 – 2000 keV)

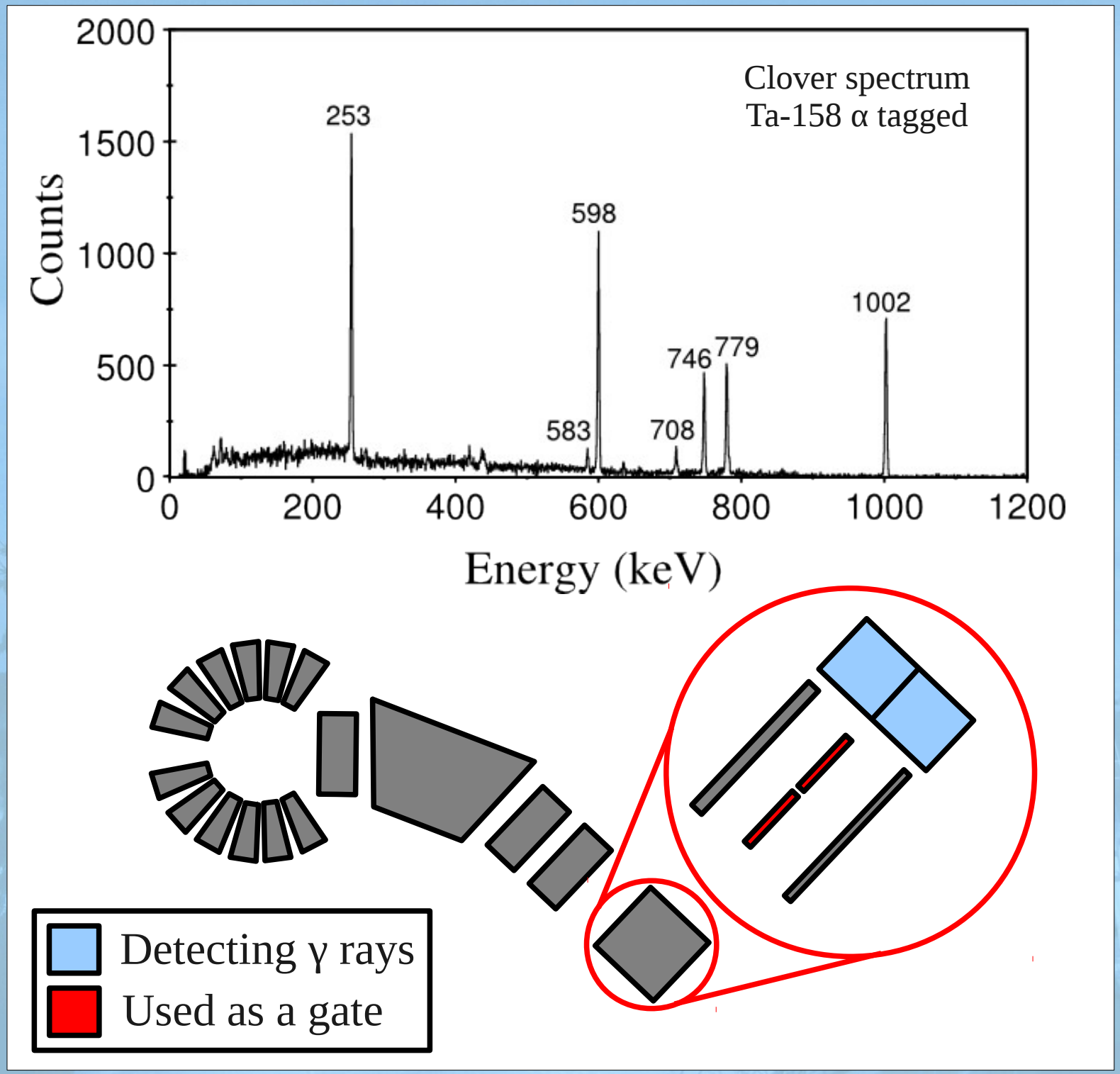
Gamma-ray emissions from isomeric states can be observed.

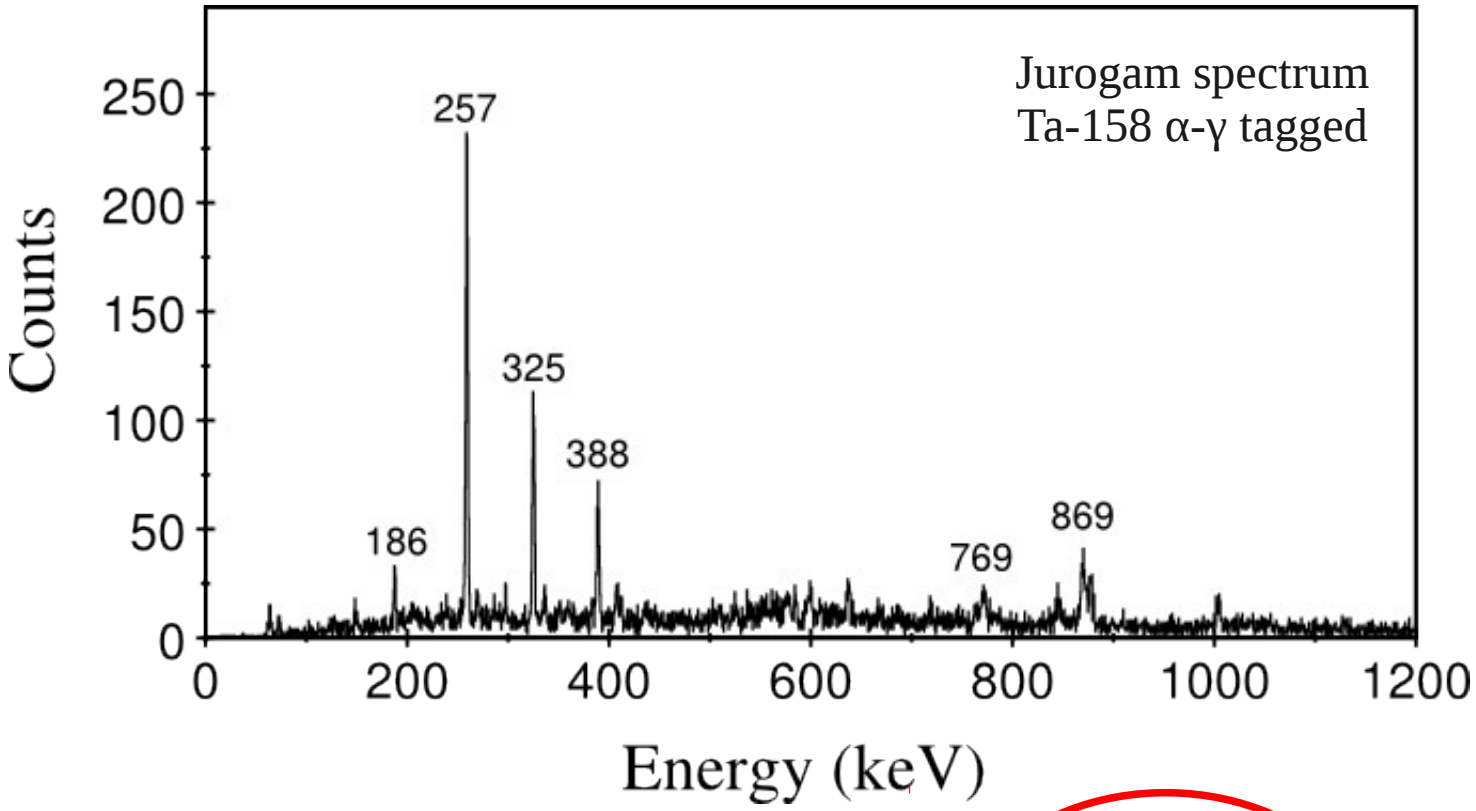
Coincidence analysis can be performed.

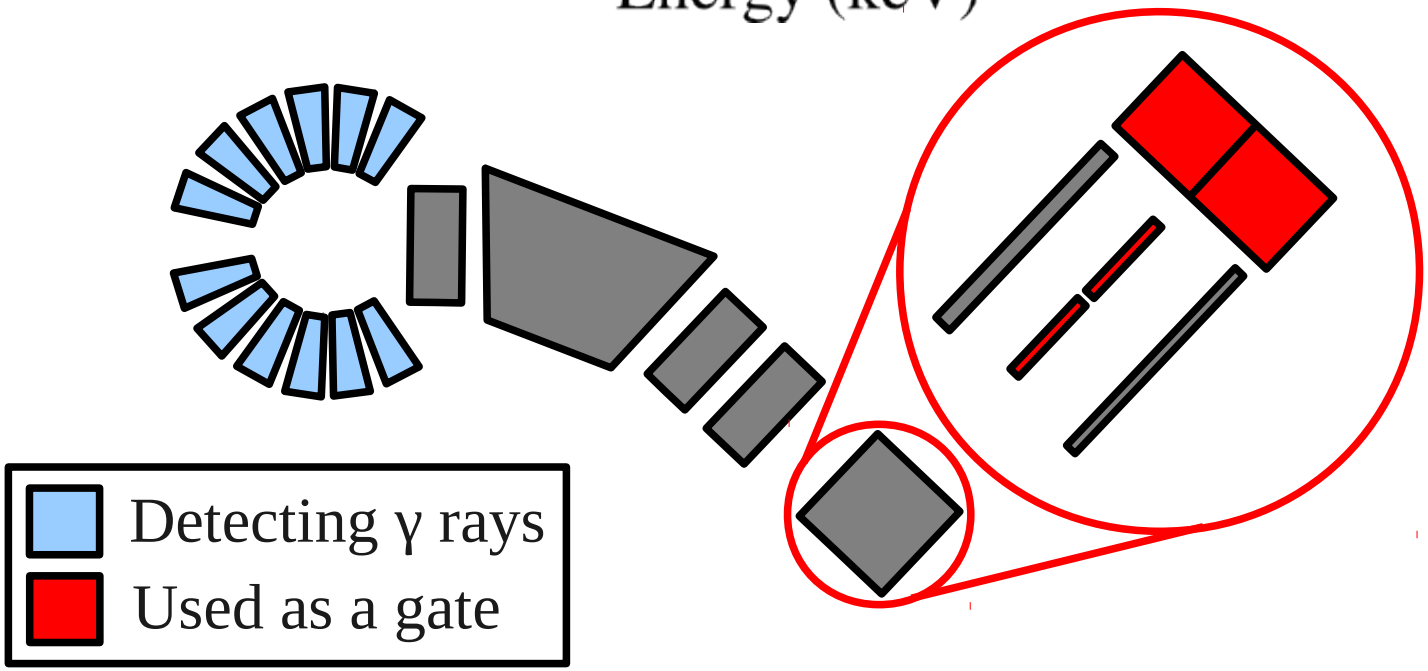



Jurogam spectrum
Ta-158 α tagged
Counts
Energy (keV)
0
2000
4000
6000
0
200
400
600
800
1000
1200
253
257
412
598
746
357
435
325
388
503
525
717
779
634

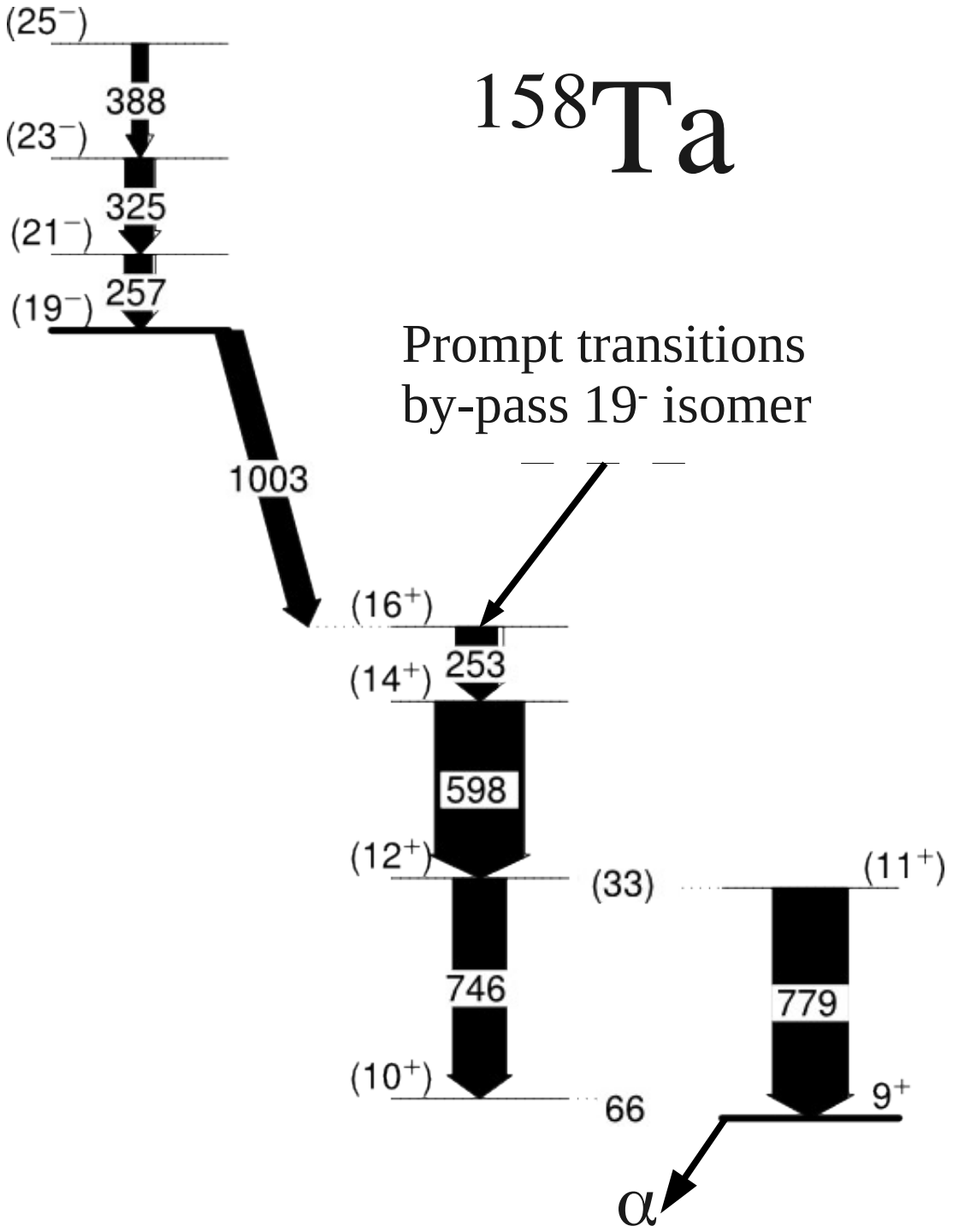

Detecting γ rays
Used as a gate

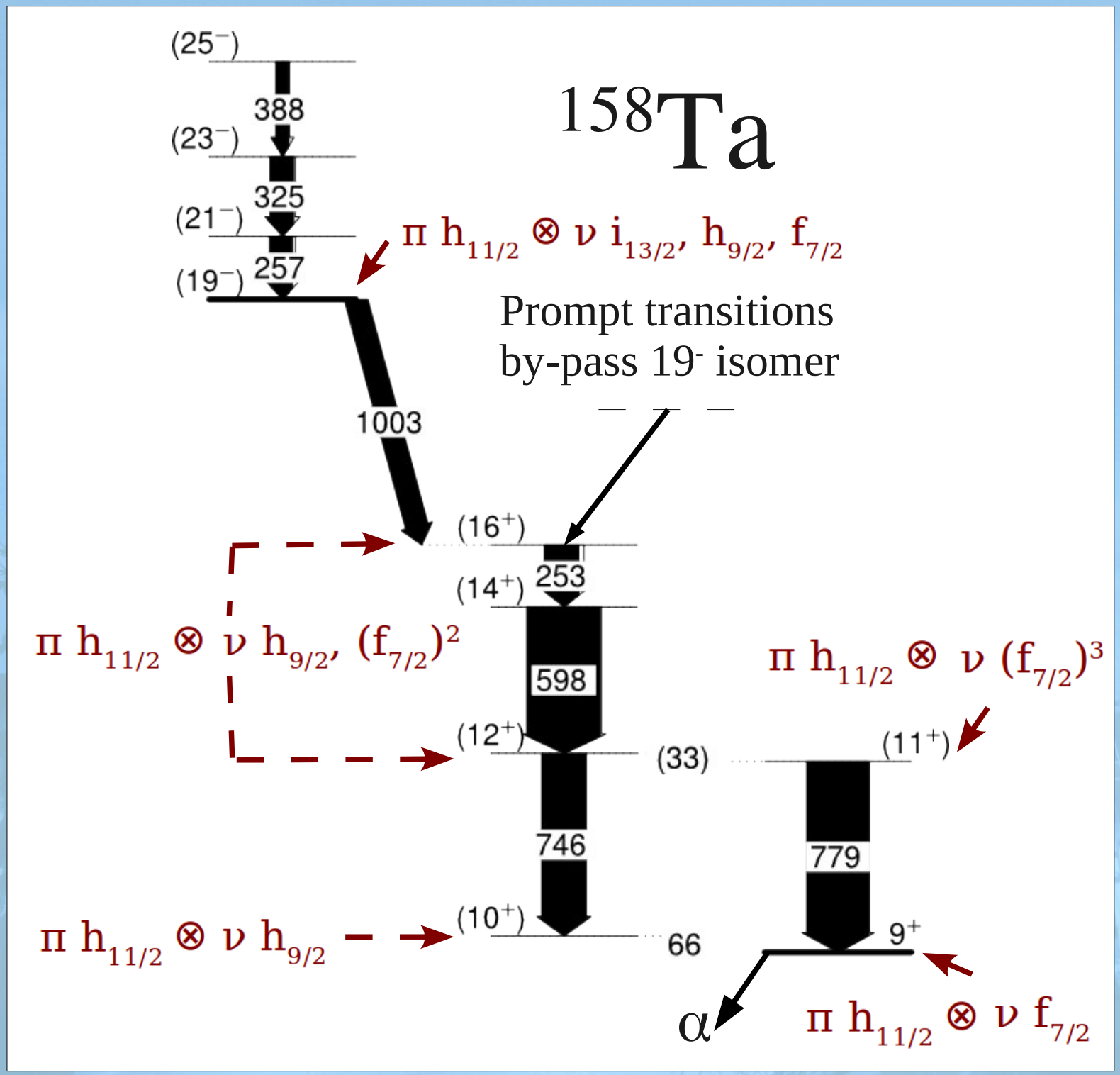

Clover spectrum
Ta-158 α tagged
Counts
Energy (keV)
253
598
583
708
746
779
1002
0
500
1000
1500
2000
0
200
400
600
800
1000
1200
Detecting γ rays
Used as a gate

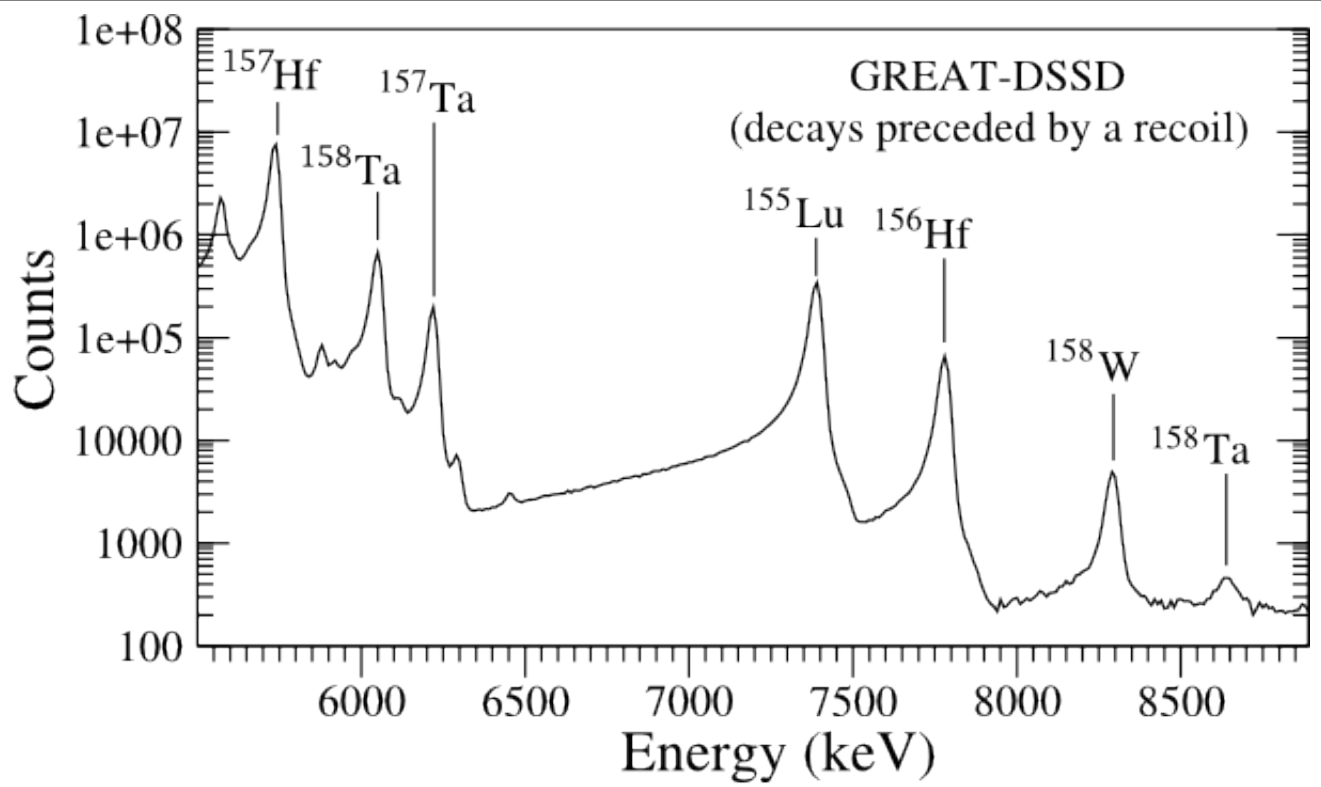

Jurogam spectrum
Ta-158 α-γ tagged
Counts
Energy (keV)
257
325
388
186
769
869
0
50
100
150
200
250
0
200
400
600
800
1000
1200

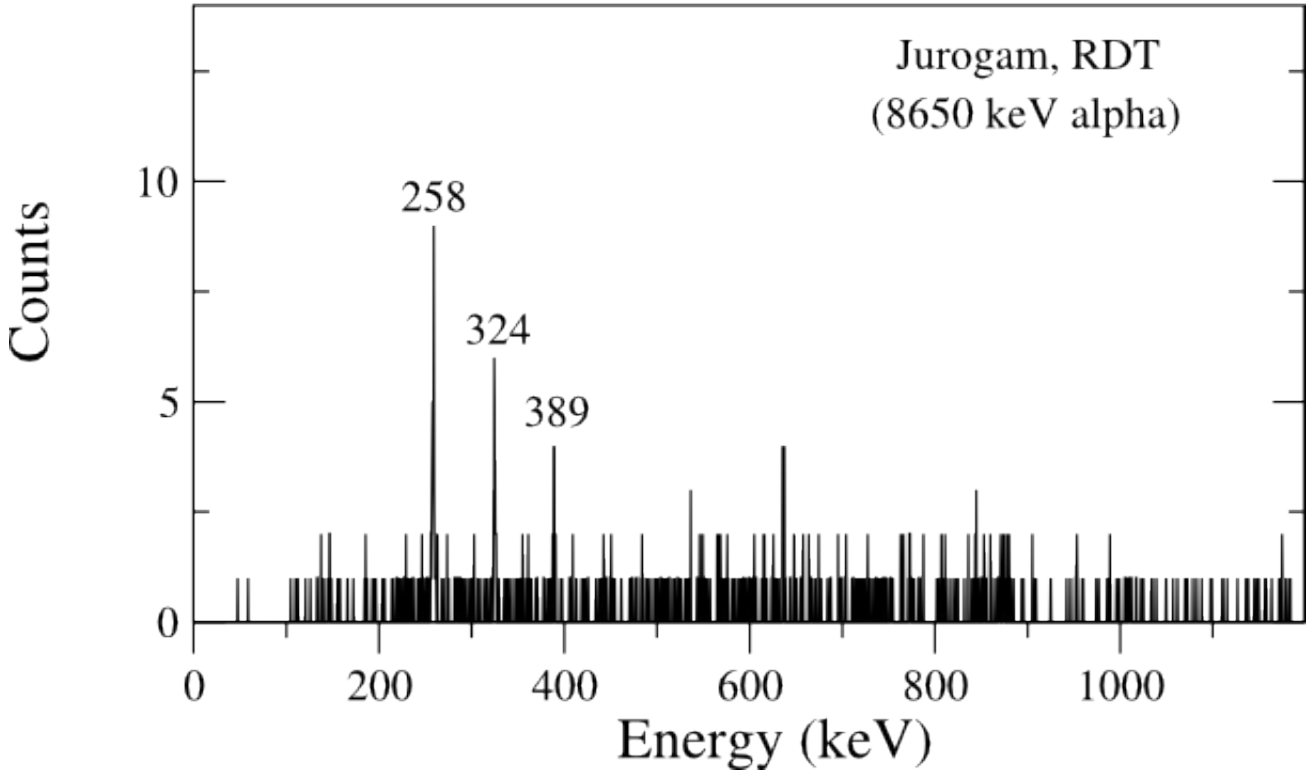

Detecting γ rays
Used as a gate

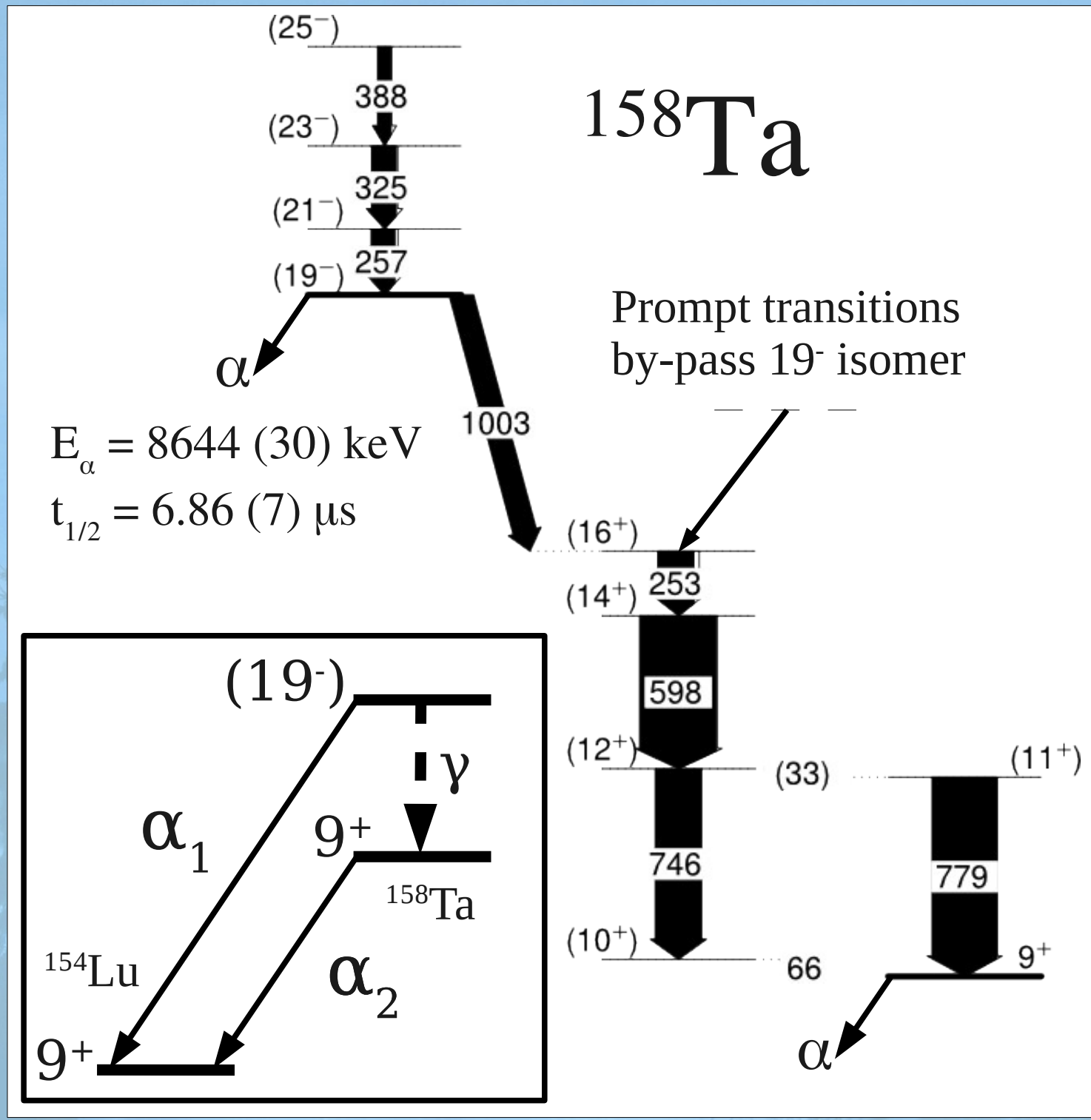
^{158}Ta


(25⁻)
388
(23⁻)
325
(21⁻)
257
(19⁻)
1003
Prompt transitions
by-pass 19- isomer
(16⁺)
253
(14⁺)
598
(12⁺)
746
(10⁺)
66
(33)
(11⁺)
779
9⁺
α

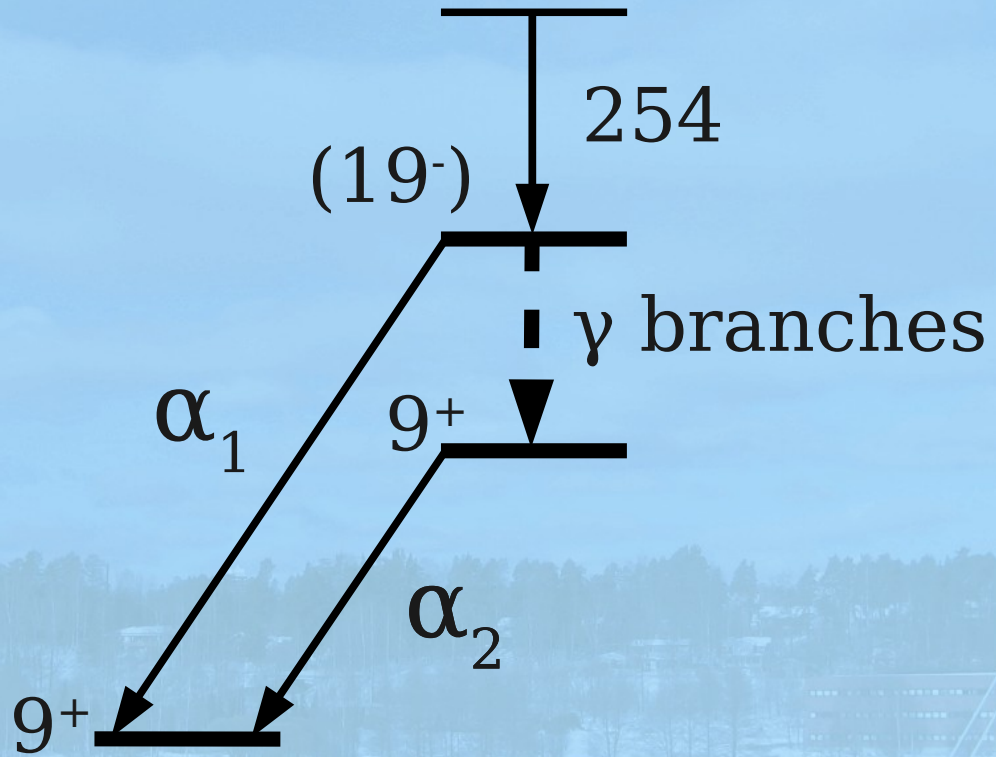

^{158}Ta
(25⁻)
388
(23⁻)
325
(21⁻)
257
(19⁻)
π h11/2 ⊗ ν i13/2, h9/2, f7/2
Prompt transitions
by-pass 19- isomer
1003
(16⁺)
253
(14⁺)
π h11/2 ⊗ ν h9/2, (f7/2)2
598
(12⁺)
π h11/2 ⊗ ν (f7/2)3
(33)
(11⁺)
746
779
(10⁺)
66
9⁺
π h11/2 ⊗ ν h9/2
α
π h11/2 ⊗ ν f7/2


GREAT-DSSD
(decays preceded by a recoil)
157Hf
157Ta
158Ta
155Lu
156Hf
158W
158Ta
Counts
Energy (keV)
1e+08
1e+07
1e+06
1e+05
10000
1000
100
6000
6500
7000
7500
8000
8500

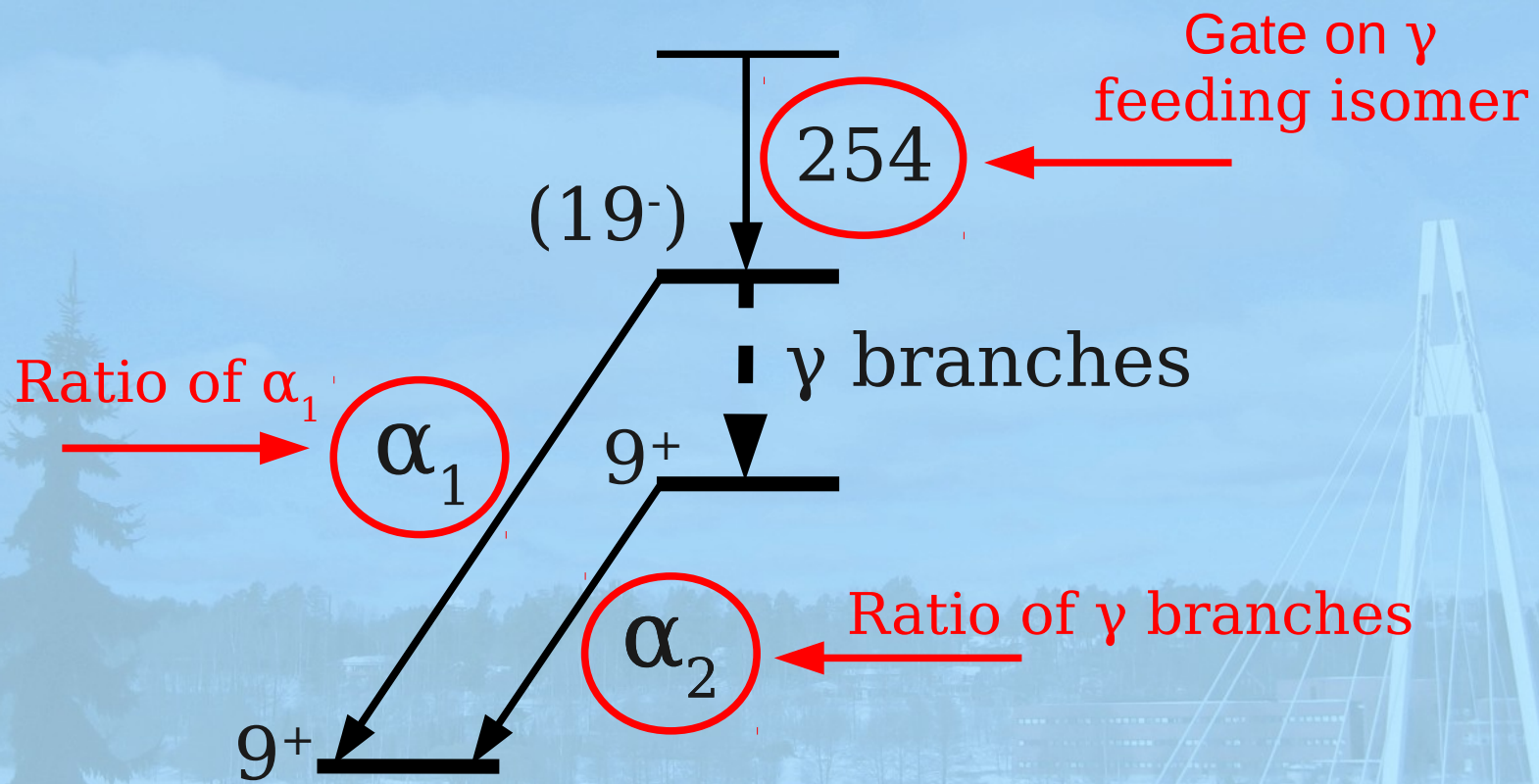

Jurogam, RDT
(8650 keV alpha)
258
324
389
Counts
Energy (keV)
10
5
0
0
200
400
600
800
1000


^{158}Ta
(25⁻)
388
(23⁻)
325
(21⁻)
257
(19⁻)
α
1003
E_α = 8644 (30) keV
$t_{1/2}$ = 6.86 (7) μs
Prompt transitions
by-pass 19- isomer
(16⁺)
253
(14⁺)
598
(12⁺)
746
(10⁺)
(33)
(11⁺)
779
9⁺
66
α
(19-)
γ
α_1
9+
^{158}Ta
^{154}Lu
α_2
9+

Obtaining branching ratios for decays from the high-spin isomer:



Obtaining branching ratios for decays from the high-spin isomer:



α_1 / $\gamma(\alpha_2)$: (0.77 +/- 0.33) %

Further analysis

One of very few known high-spin alpha decays in this region.

Why have others not been seen?

- Shorter decay times?
- Possible task for the LISA spectrometer?

How does its hindrance compare with those of known decays?

R Carroll[1], D T Joss[1], R D Page[1], J Uusitalo[2] , I G Darby[1], S Eeckhaudt[2], T Grahn[2], C Gray-Jones[1] , P T Greenlees[2], P M Jones[2], R Julin[2], S Juutinen[2], M Leino[2], A P Leppanen[2], M Nyman[2], J Pakarinen[2], P Rahkila[2], P J Sapple[1], J Saren[2], C Scholey[2], D Seweryniak[4], J Simpson[3], D Warner[3] and H Watkins[1]

[1]Department of Physics, The University of Liverpool

[2]University of Jyväskylä

[3]Daresbury Laboratory

[4]Argonne National Laboratory

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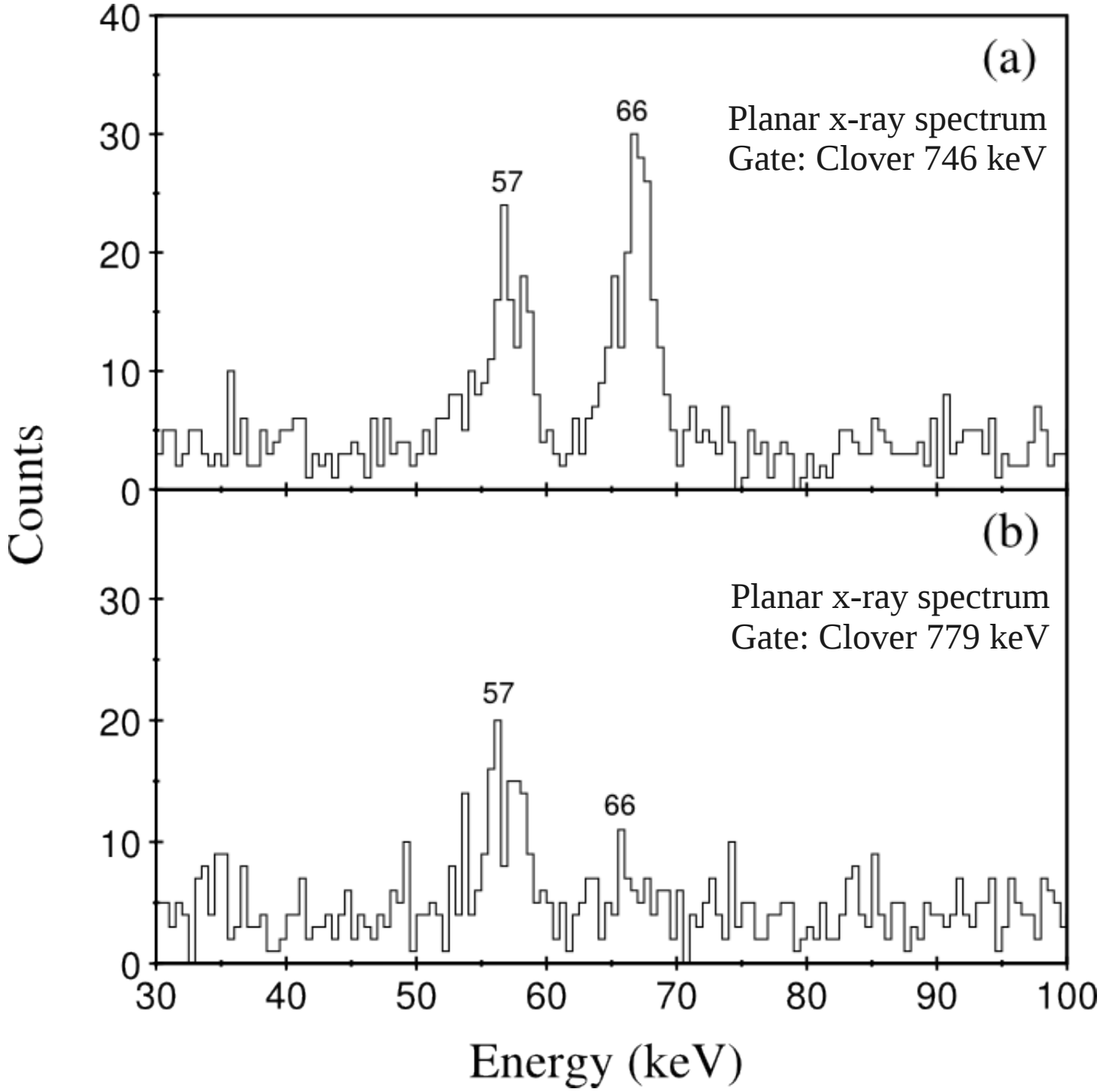
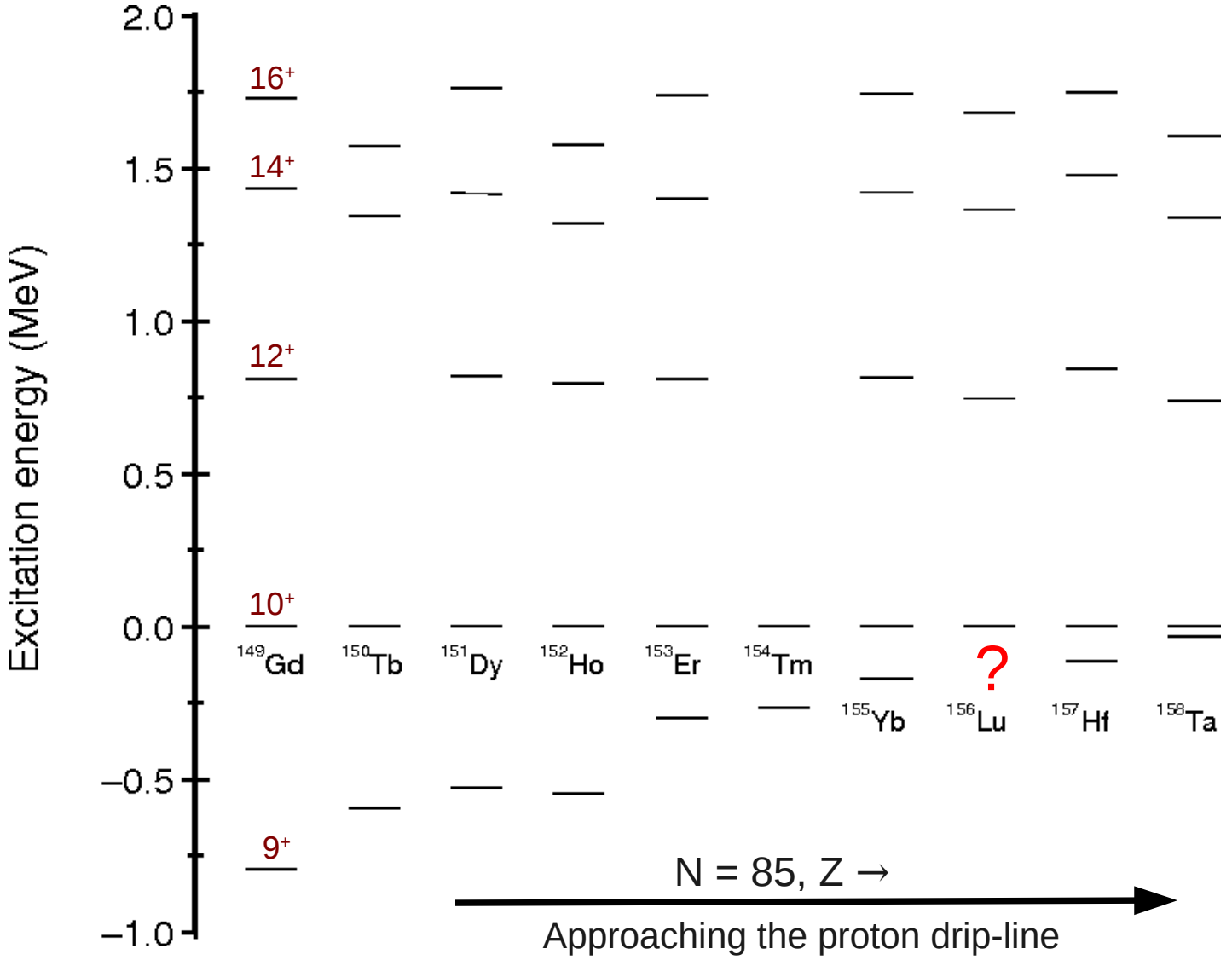
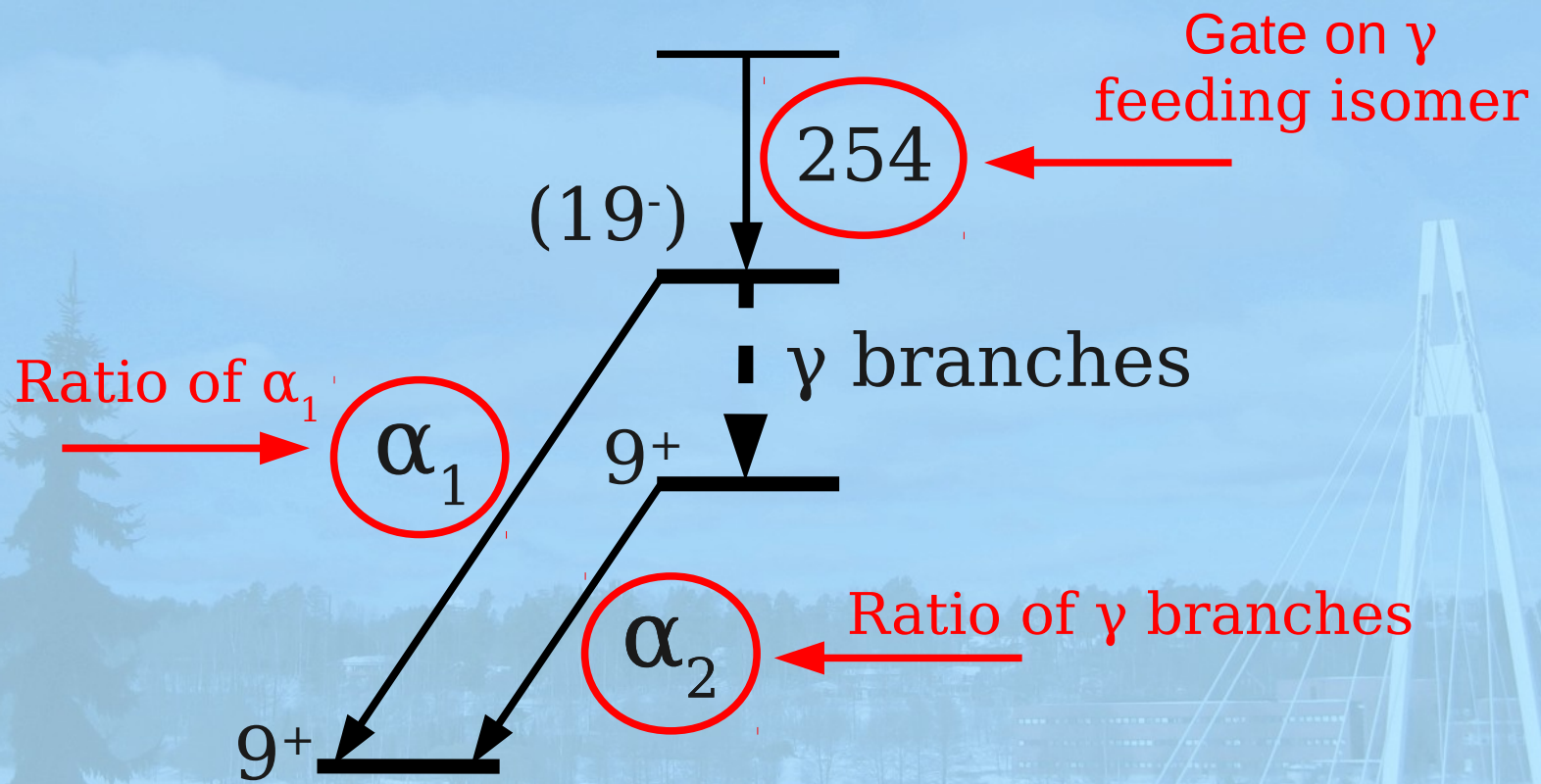

(a)
Planar x-ray spectrum
Gate: Clover 746 keV
57
66
(b)
Planar x-ray spectrum
Gate: Clover 779 keV
57
66
Counts
Energy (keV)
0
10
20
30
40
30
40
50
60
70
80
90
100


Excitation energy (MeV)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
16+
14+
12+
10+
9+
149Gd
150Tb
151Dy
152Ho
153Er
154Tm
155Yb
156Lu
157Hf
158Ta
?
N = 85, Z →
Approaching the proton drip-line

Obtaining branching ratios for decays from the high-spin isomer:



α_1	:	(0.76 +/- 0.33) %
α_2 or γ	:	(99.24 +/- 4.38) %